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PROGRESS IN GROUND RADOMES

(See page 157)

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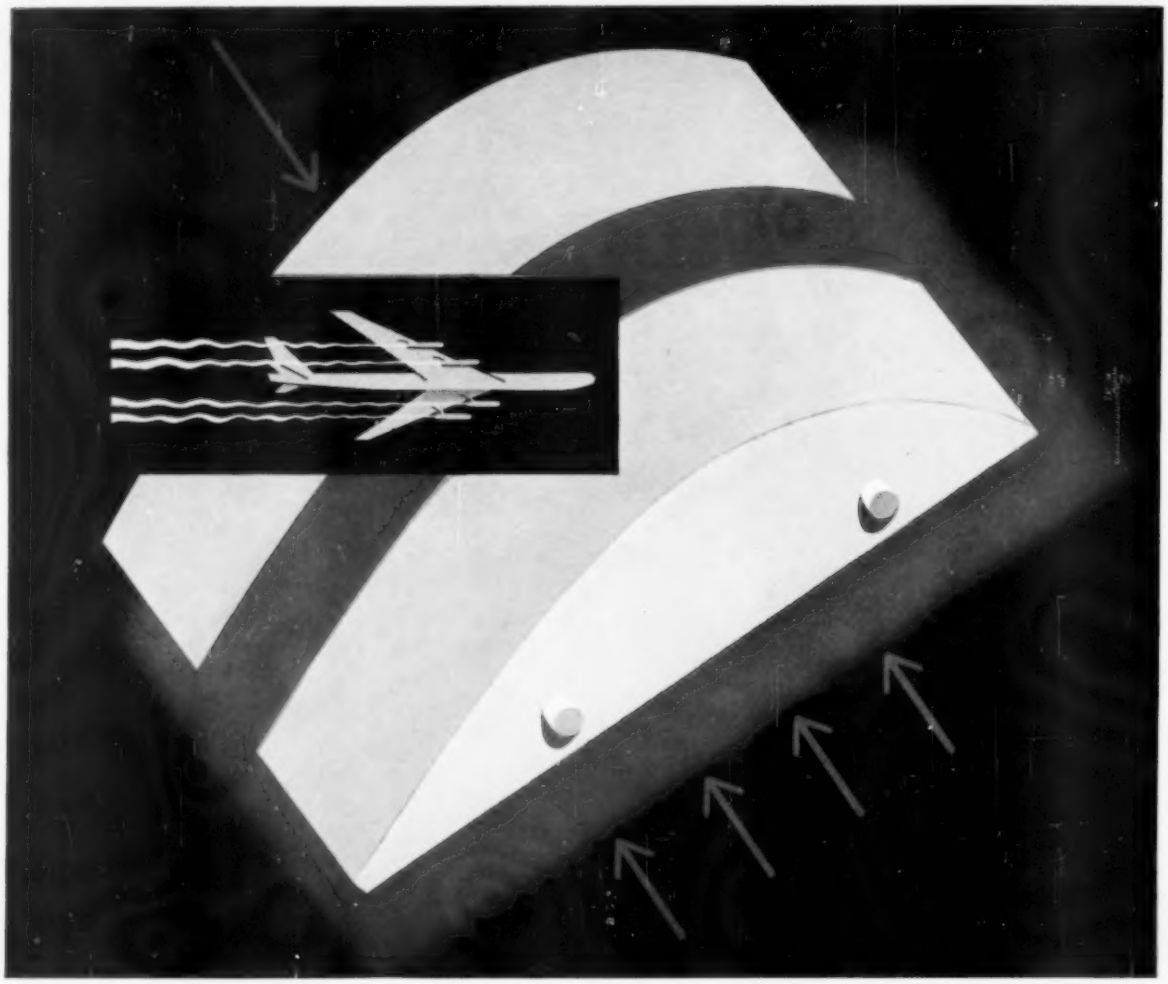

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U.S.I. POLYETHYLENE NEWS

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FEBRUARY, 1959 — U.S. INDUSTRIAL CHEMICALS CO., DIVISION OF NATIONAL DISTILLERS AND CHEMICAL CORPORATION, 99 PARK AVE., N. Y. 16, N. Y.

Packaging Notes

New rim seal packaging machine that effects considerable savings in time and packaging film is being placed on the market. The hand-operated machine was designed for use in small food packaging operations, such as are common in super markets. The machine seals polyethylene film to the rim or lip of the food tray or container in a single operation. By eliminating the extra film that normally is folded and sealed under the tray, the machine reportedly saves almost 60% of the amount of film needed to make a sealed package. It is claimed that the machine can produce three to four times as many packages in a day as can be made by present hand wrapping methods.

The machine employs an electrically heated and thermostatically controlled upper section which is brought down on the film to make the rim seal. The heat sealing surfaces can be changed quickly for almost any size or shape of container. A set of sealing shoes for conventional package sizes and shapes is included with the machine.

Pressure-sensitive, paper-backed polyethylene tape solves problems of joining and patching poly film used in agriculture and as a water vapor and dust barrier in the construction field. The tape is easily applied by removing the paper backing and firmly pressing the tape smooth. The tape meets general building requirements, including FHA specifications.

Grain and silage can be packaged and preserved in poly bags, according to a study made at a leading Midwest agricultural school. Previous attempts to accomplish this with conventional bags failed because the bags permitted air to enter the package, spoiling the high moisture silage. Polyethylene reportedly lets gas escape, but prevents air from entering.

A new process permits polyethylene coated bags and cartons to be run on standard glue-sealing machinery at high speeds, using low-cost dextrin and starch adhesives. The process is expected to increase sharply the use of polyethylene-coated materials for packaging.

Possible applications include boxes for chlorinated powdered detergents, cereals, cake mixes and other products requiring sift-proof containers. Need for a loose inner liner would be eliminated. Polyethylene-coated cartonboard for frozen food packages would also cut costs by eliminating the need for overwraps.

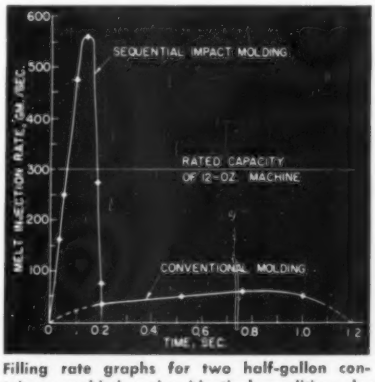
First commercial use for the process is in packaging personal hygiene products in a box made of polyethylene-coated paperboard. The coating replaces a glassine-paper laminate.

Sequential Impact Molding: New Technique Increases Output, Simplifies Fill Control

Method Based on Precisely Timed Release of Precompressed Melt

A radical improvement in the still new technique of impact molding was announced recently. Called Sequential Impact Molding (SIM), the new method reportedly yields from 30 to 50% more pounds of finished pieces per hour than the best yields for the same equipment employing conventional procedures. Mold filling rate is said to be increased six-fold.

In ordinary impact molding, the melt is precompressed, then "exploded" into all the mold cavities at one time. With SIM, the cavities are filled in carefully timed sequence, with each cavity receiving the full pressure of the injection setup. Sequencing is achieved by timed opening and closing of the valves in a multiple-nozzle manifold. The advantage of this method over sequenced valve gating is that all the special equipment is in the injection end of the machine rather than in the mold. One valving setup may be used for many different molds.



Filling rate graphs for two half-gallon containers molded under identical conditions by sequential impact molding and by conventional means.

Faster Filling Speed

In addition to increased output, one of the biggest advantages of SIM is reported to be the speed with which the cavities are filled. With SIM, cavity filling is so fast that mold temperature is no longer critical and amount of flow into the mold is more easily controlled. This speed also eliminates core shifting and weld lines by reducing the usual large, around-the-cavity pressure gradients that are responsible for core shifting in bottom gated cavities. SIM is also said to eliminate warping of thin sections caused by locked-in stresses.

Sequential opening of the valves also reduces clamp requirements, since only one cavity or group of cavities is filled at any one time. Thus, clamping force needed is much less than if all the cavities were filling together. This permits an increase in the number of cavities without undue concern for clamping capacity.

Equipment for SIM is being made and sold under license from the company which developed the technique. Both new molding machines and conversion kits for adapting existing equipment are being offered.

Booklet Describes Chemical Growth of National Distillers

A full color brochure describes the growing contribution to the chemical industry of National Distillers and Chemical Corporation. The 36-page booklet takes readers on a photo tour of plants operated by U.S.I. and its affiliated companies. Products of these operations — polyethylene, petrochemicals, agricultural and industrial chemicals, corrosion-resistant metals and high energy fuels — are described.

The brochure may be obtained by writing Editor, U.S.I. Polyethylene News, U.S. Industrial Chemicals Co., 99 Park Avenue, New York 16, N. Y.

To Wrap 1500-Mile Pipeline With Polyethylene Tape

Work has begun on a $3 million contract to wrap an entire 1500-mile pipeline with polyethylene tape. Although poly tape has been used extensively as a protective wrapping for pipelines, this reportedly is the first time that a major system has been completely wrapped with tape.

The pipeline runs from Baton Rouge, La., to Cutler, Fla. and is made of pipe varying from 18 to 24 inches in diameter. The contract represents the largest single order ever placed for a protective pipe coating of any kind.

Poly Wraps Win 32 Awards In Packaging Competition

Polyethylene bags and wraps took a total of 32 prizes recently in the third annual Flexible Packaging Competition, sponsored jointly by the National Flexible Packaging Association and Paper, Film & Foil magazine. Poly packages won more awards than were given to all other packaging materials combined. The top award of the competition went to a polyethylene package for girdles.

U.S.I.

Vol. IV, No. 1

POLYETHYLENE PROCESSING TIPS

PRINTING ON POLYETHYLENE FILM: HOW TO GET BEST RESULTS IN FLEXOGRAPHIC PRINTING

In the last edition of "TIPS" (Vol. III, No. 6) a review was made of the methods for pretreating polyethylene film surfaces so that commercially available printing inks will adhere well. Since most commercial printing on polyethylene film today involves the use of flexographic techniques, this method of printing film after it has been surface-treated has therefore been chosen as a topic for discussion. Film processors who have just acquired flexographic printing equipment and those who plan to add such equipment should find this of particular interest.

Performance of Flexographic Inks

Because polyethylene is nonabsorbent toward inks, even after surface-treating, the commercial flexographic inks developed for printing on this material are of the nonabsorbing type. They are relatively fast-drying, and usually possess high gloss. They do not require high temperatures for drying.

In general these inks are composed of a solvent vehicle, a resin binder and pigment plus various additives to impart gloss, etc. The drying speed of an ink, important in rapid multicolor printing, depends on the solvent vehicle. Combination solvents are generally used for flexographic inks so that drying speed can be varied readily by changing the solvent mixture ratio. Where hydrocarbon-type solvents such as naphtha are used, *synthetic rubber* plates and rollers must be employed to prevent swelling and deterioration.

While the resin binder in the ink acts as the adhesive agent, the gloss and antiblock additives play an important role. Formulations must be checked constantly by the ink manufacturer for proper adhesive properties.

Some Printing Hints

Processors should keep in mind that solvents used for different types of inks—such as hydrocarbon inks and alcohol inks—are usually not miscible and should not be mixed.

Most flexographic inks require constant mixing by recirculation or other methods to maintain color uniformity.

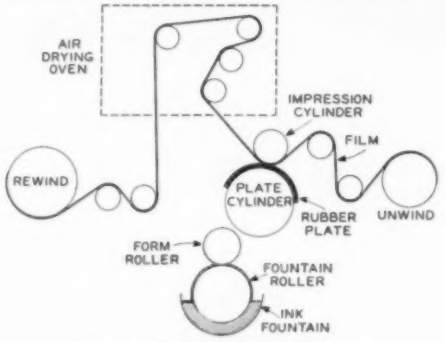
The first ink down in a multicolor printing operation must be the fastest drying and each successive color can be slower. Also, in a multicolor operation, it is desirable to print lighter colors first, followed by darker inks. This prevents noticeable color contamination that would otherwise occur.

Here is an important fact to remember in printing on extremely thin gauge film. Such film is usually surface-treated very lightly, thereby increasing the possibility of poor ink adhesion. In this case it is often possible to place a base ink on the film surface over the same areas to be printed later. This base ink may possess high adhesion but poor gloss and antiblock. However, overprinting with other inks will remedy these poor qualities. The adhesion of ink-to-ink is much greater than ink-to-polyethylene, and so overprinting with glossy inks will result in both desirable adhesive and appearance properties.

Tests for Satisfactory Printing

If the processor does not extrude, surface-treat and print all in line, it may sometimes be necessary to test unprinted film to see if it has already been treated. Visual inspection will not give the answer. However, ability of the film to be wetted by water is increased after treatment, so that a determination of wetting characteristics will reveal the extent of treat.

The Scotch Tape test, described in U.S.I. Polyethylene Processing Tips, Vol. III, No. 6, as a control in the surface-treating operation, is also used to determine how well the ink is adhering to the printed film as it comes off the press. Here the tape is applied to the printed film after drying. It is then drawn back slowly over about half its length and rapidly pulled off the remaining area. Printing is satisfactory if no ink is removed from the film.



Schematic diagram of flexographic printing process.

U.S.I. Will Advise

This has been only a brief summary of some of the more important phases of flexographic printing on polyethylene film. As a manufacturer of polyethylene resins, U.S.I. has studied the subject in some detail and is equipped to help the processor with his printing problems.

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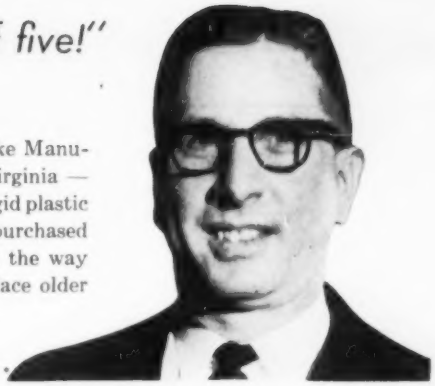

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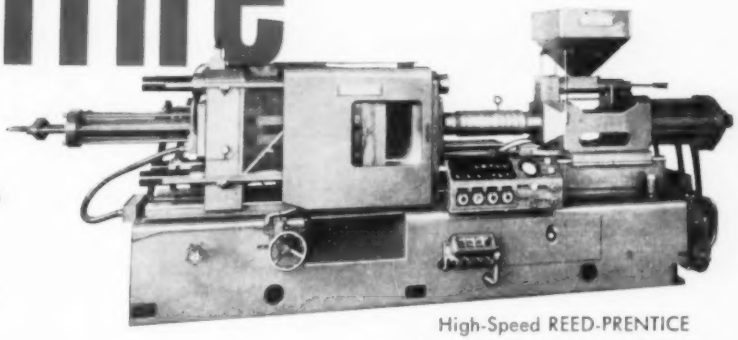

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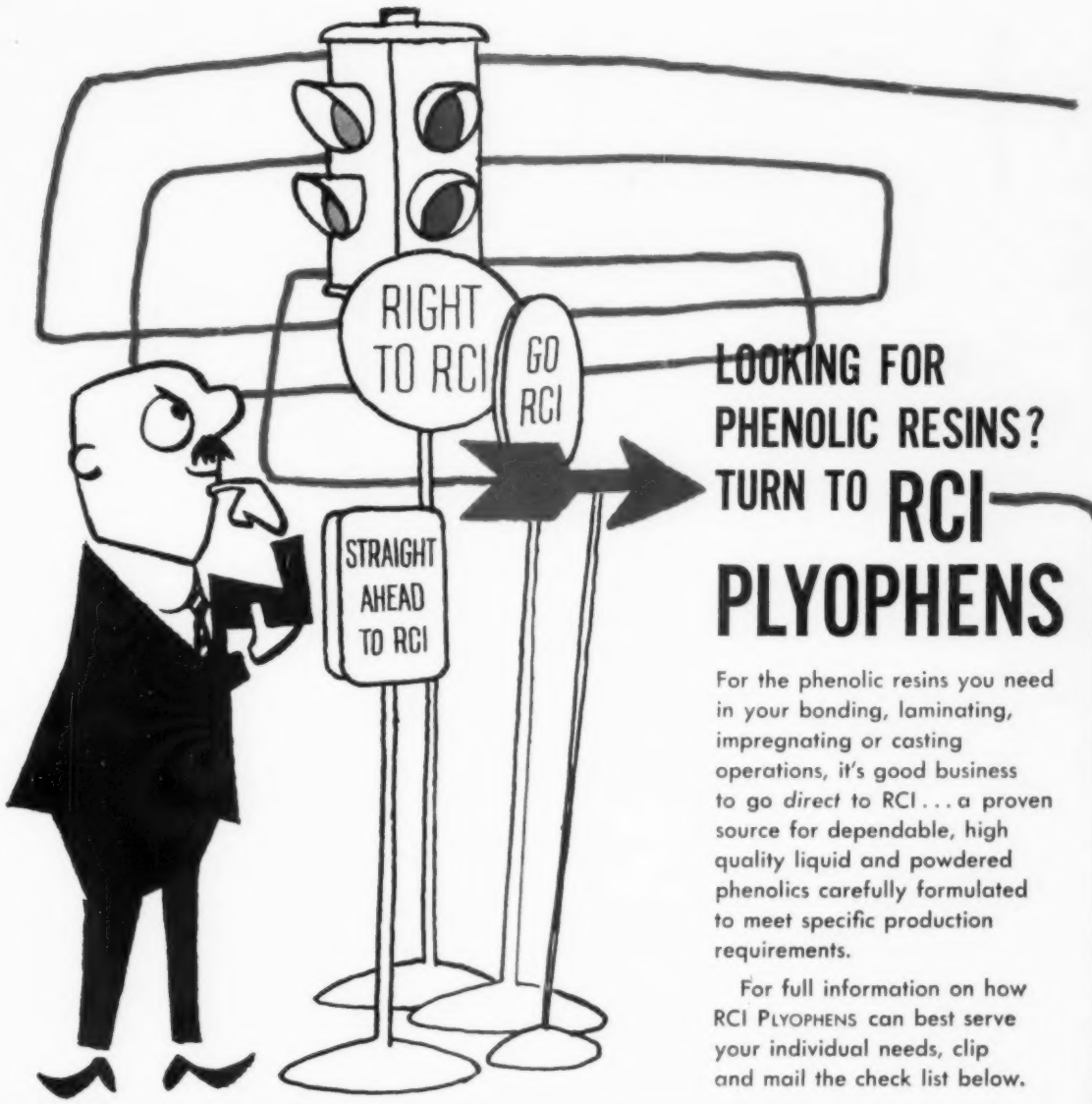

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EDITOR'S NOTEBOOK

What's Ahead for SPE Journal Readers

There has been a flurry of activity lately on the *SPE Journal* to bring to you more information about those activities in which a large segment of SPE members are engaged. Last November we initiated a new feature, Polymer Science, under the editorship of Dr. Irvin Wolock. This issue starts a new series on Reinforced Plastics, and forthcoming issues will reveal even further progress. Some of the additions to the Journal staff are described below.

REINFORCED PLASTICS

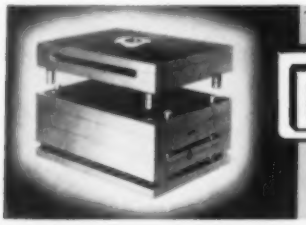
This month we published the first series of a new technical feature, Reinforced Plastics, edited by George Lubin. Mr. Lubin brings to you in this issue a comprehensive survey on reinforced plastics ground radomes by S. C. Nilo of MIT Laboratory (see page 157). He will endeavor to bring you, on an alternate month schedule, review articles and new technical information on the various aspects of reinforced plastics. Mr. Lubin is Staff Consultant with Grumman Aircraft Co. and Chairman of SPE Reinforced Plastics PAG. He received his B.S. in Chemical Engineering in 1936 at City College of New York, and has subsequently completed his M.S. His work in plastics began in 1936 with Columbia Records, where he worked on electroformed molds and the use of vinyl plastics in records. During the war he headed the Plastics Group at the Naval Materials Laboratory, where he won commendations for developing methods and equipment for testing plastics materials. In 1947 he became director of research for Bassons Industries Corp., and has since served as technical director for Lawrence Wittman & Co., and consultant for York Research. In 1957 he started with Grumman.

MOLDMAKING

The *SPE Journal* has been fortunate in obtaining the services of Ernest J. Csaszar as feature editor on a new feature to start soon on Moldmaking. Mr. Csaszar is Past President of SPE's Newark Section and sales manager of Newark Die Co. He graduated from Newark College of Engineering in 1940 with a B.S. in Mechanical Engineering. Previous to his present position he was with Universal Plastics Corp., and with Eagle Tool and Machine Co. From 1945 to 1946 he was stationed at the Naval Ordnance Laboratory working on plastics applications. Ernie will endeavor to keep *SPE Journal* readers abreast of the latest developments and techniques in moldmaking.

EXTRUSION

Bruce H. Maddock, project leader in the Extruded Products Division of Union Carbide Plastics Co., will replace Robert Sackett as editor of the Speaking of Extrusion feature beginning next month. (see page 166 this issue). Mr. Sackett will continue his work as a member of the Journal Editorial Advisory Board. Mr. Maddock graduated from the University of Michigan in 1934 with a B.S. in Engineering Physics. Starting with the Bakelite Company in 1935, he participated in the development of electrical insulation materials and extrusion processes for wire insulation. From 1942 to 1945 he served as chief engineer of the Intelin Div., Federal Telephone and Radio Corp., then returned to Bakelite for further work in wire insulation materials.



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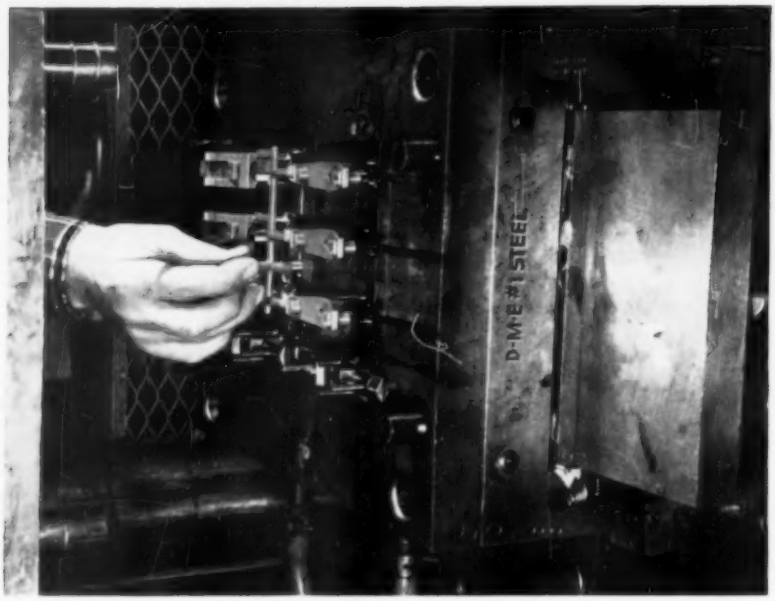

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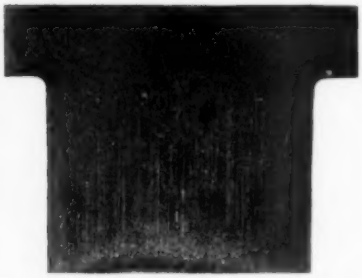

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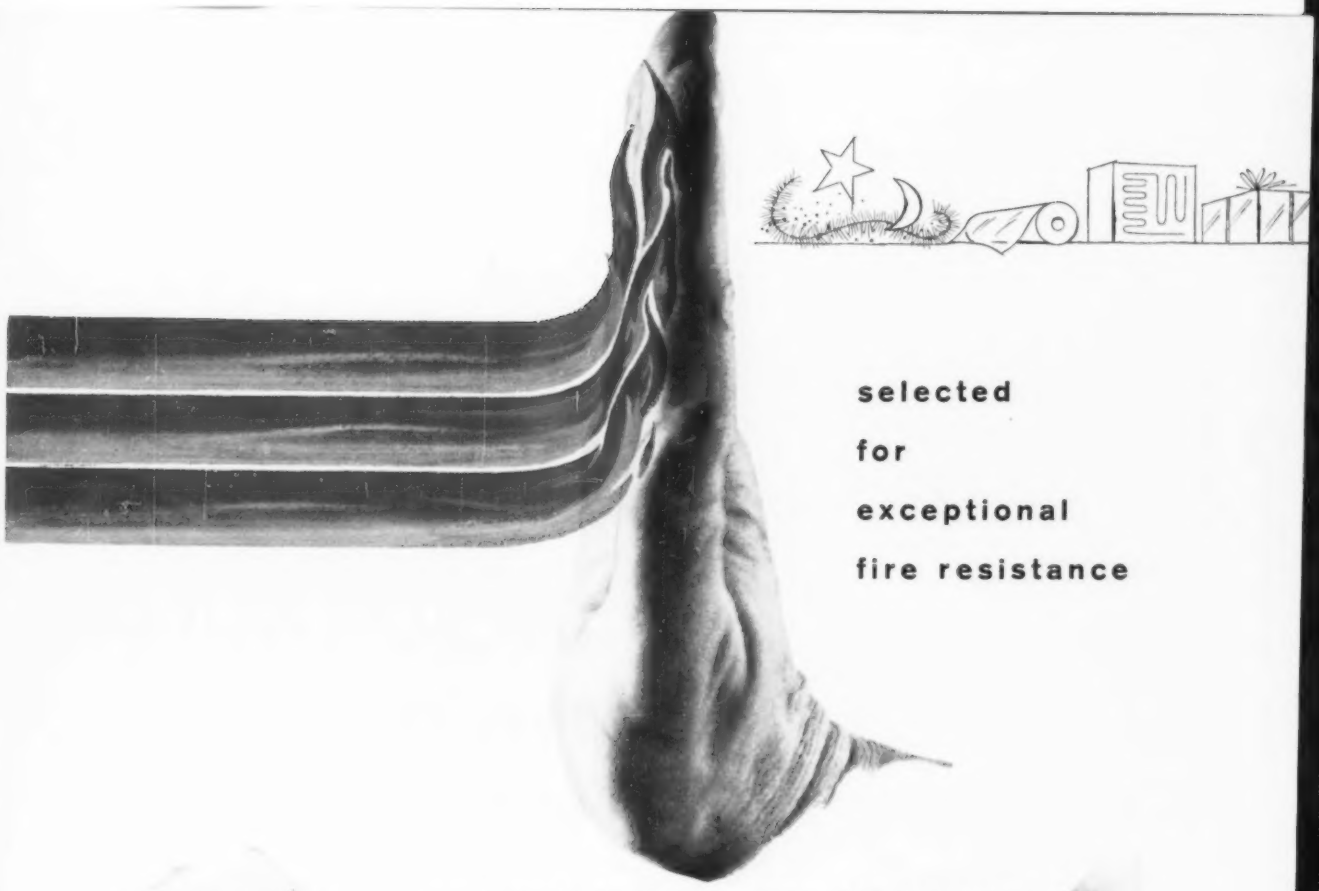

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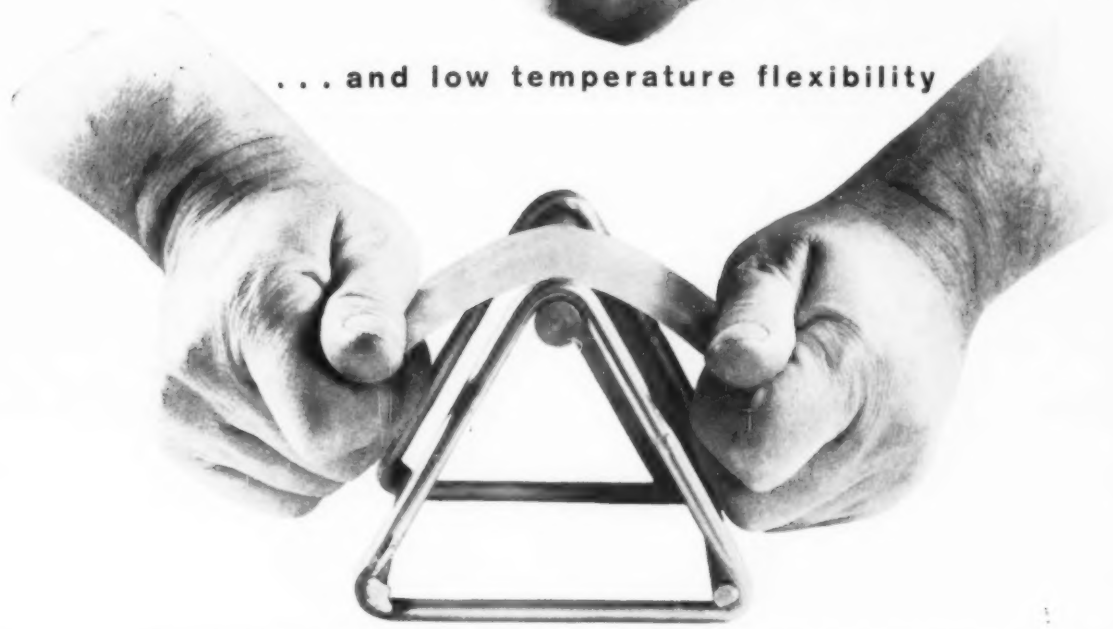

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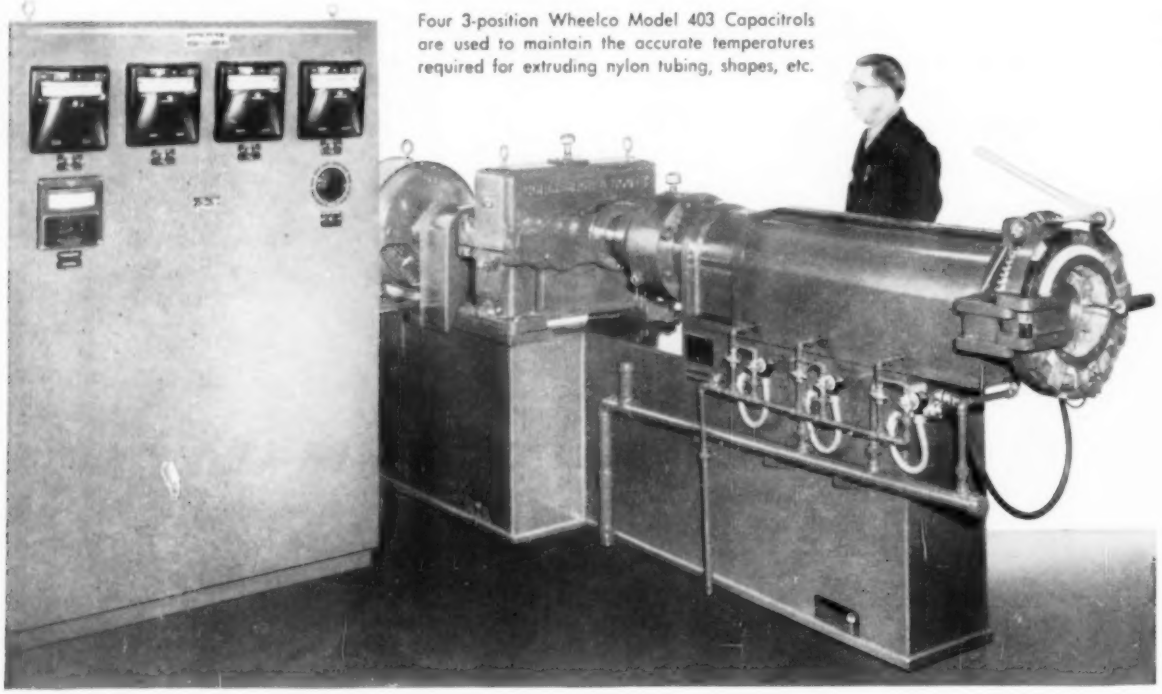

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PLASTICS ENGINEERS JOURNAL

Volume 15, Number 2, February, 1959

Engineering Molded Parts for Business Machines

A step-by-step analysis of how the plastics laboratory in a captive molding plant coordinates operations from original design to end use to achieve accuracy and dependability of molded parts under all conditions of load and environment.

Byron W. Nelson
The National Cash Register Co.
Plastics Laboratory

IN THE BUSINESS MACHINE INDUSTRY we have the situation where many different materials play small but highly important functions in the end product. Under circumstances such as these you will usually find that specialized groups are responsible for a particular type of material. It is the function of this group to control new material specifications, raw material shipments, material assignment to engineering parts, furnish technical assistance to part design, tooling and production, and to conduct plant ad field trouble shooting. Since plastics is one of these highly important materials, our Plastics Laboratory operates in the fashion outlined above, where we are in constant contact with all phases of an item from its original design to its production use. We feel that this is a decided advantage since extremely valuable experience is gained. Even more experience becomes available when a company has its own (or captive) molding plant.

Our methods of handling a part from its original basic function to its production end-use are carried out according to the following general phases:

A. Part Function Analysis
B. Part Design Analysis
C. Material Assignment
D. Part and Design Tryout
E. Production Planning and Tooling

Business machines are extremely complicated and may be constructed of all mechanical, mechanical plus electrical and electronic, or all electrical and electronic systems. We find that the combination systems of mechanical and electrical functions present the most varied of dimensional tolerances, load and environmental characteristics. This type of machine is made up of thousands of parts of close dimensions which must operate accurately under all conditions of load and environment. These parts may have optical, decorative, mechanical, electrical or combination functions. The functions may be static or operational, continuous or intermittent, impact or sliding movement, all of which create many factors for ultimate consideration. This then, generally means that these parts must be made and held to close limits at all times. Under these conditions, it is necessary that all phases or part function, design, and material assignment must be coordinated very closely. In our studies, therefore, we analyse by attempting to find the answers to the following questions:

Part Function

1. Is the part external or internal?
2. If the part is external, is it purely decorative or is

This paper was presented at the Regional Technical Conference sponsored by the Philadelphia Section of SPE.

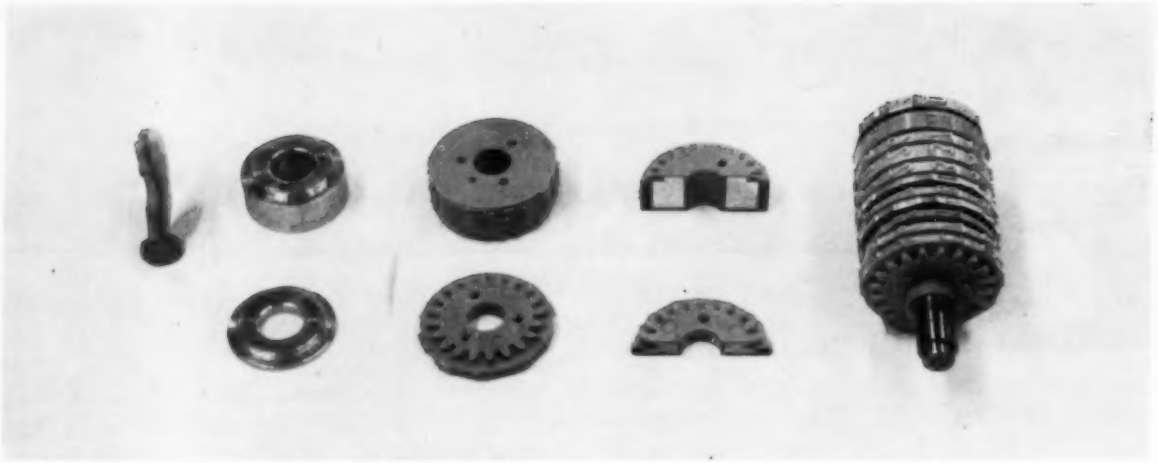

Figure 1. Nylon type wheels—left to right—Cross section of original insert tryout; Final insert design; Finished molded parts; Cross section showing inserts; Line-up of engraved metal and molded nylon wheels.

it functional as well? Color and appearance are always considerations in an exterior part.

3. Is it moving or stationary?
4. Is it subjected to load? If so, is the load static or operational, intermittent or continuous, sliding or impact? What is the magnitude of the force? The answers to these questions determine whether an anti-frictional, a high impact, a rigid, a flexible, or a low cold flow material must be used.
5. What are the maximum and minimum temperature and humidity conditions to which the part must be exposed? The part must not distort or malfunction under the extremes of these conditions.
6. What are the dimensional tolerances required for the part to maintain? We find that in some cases these tolerances must be maintained when operating but not when static.
7. Does the part in any way have to act as an electrical insulator and to what extent?

Part Design

1. Does the part have as uniform a section as possible? This is necessary to obtain even shrinkage, no warpage, and absence of either internal or external shrinkage marks.
2. Does it have fillets at all corners to reduce part breakage and to facilitate mold cavity machining?
3. Are strengthening ribs at proper places and so designed as to reduce shrinkage marks to a minimum? Can the part be redesigned in order to utilize contour instead of ribs for strength?
4. Will metal inserts be required to strengthen or maintain dimensional stability in the part?
5. If inserts are functional, are they properly locked into the assembly? Is there enough material around them to prevent cracking due to shrinkage or warpage due to expansion or contraction? Are they designed to obtain even section of plastic material

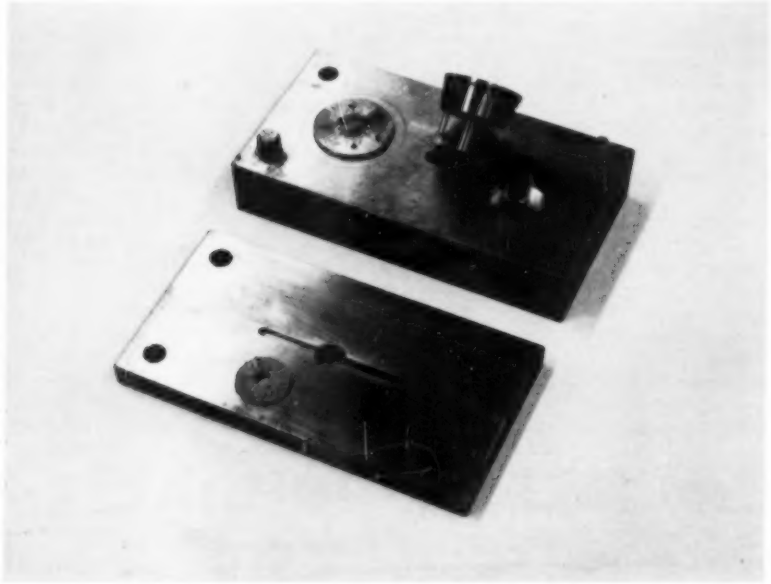

Figure 2. Experimental hand mold for nylon tape wheel with one insert cavity removed showing tapered design to cause locking of matrices when closed.

around them to prevent shrinkage marks? Are they placed so that they can be held in the mold?

6. If the part is tied down rigidly to a metal piece, have provisions been made to prevent breakage or distortion due to differences in thermal coefficients of expansion or moisture absorption or loss?
7. Has the part been designed with proper draft angles to insure removal from the mold?
8. Are there undercuts which will require expensive retracting or collapsible sections in the mold?
9. Is it designed so that simple parting lines in the mold can be used? Will this parting line occur at a prominent or working surface which will require expensive cleanup?
10. Is it designed so that it can be gated at the heaviest section without excessive degating operations?
11. Are the dimensional tolerances liberal enough to be realistic for plastic materials, or are they so close that selective inspection (at high cost) will be required?

Material Assignment

1. Will any plastic material satisfy all the requirements set forth by the above analysis?
2. What has the above analysis shown to be the most important requirements for the material? A thorough knowledge of all plastic materials is necessary to allow correct application.

Many times the applications are simple enough that no further checking is required, and generally a choice of material can now be made.

Part and Design Tryout

Other times the application may be of a very complex nature and the known properties of a material are not enough to determine whether it will function under a peculiar set of conditions. When this occurs, we must then prepare models or prototypes, either by machining from solid stock, or molding in a single cavity hand mold. These parts are then subjected to the actual conditions under which it must operate (either in an existing machine or in a test fixture which simulates actual conditions). These tests are always run to the expected life of the machine. If the material and part are satisfactory at this point, we will then produce enough parts to allow us to obtain a representative field tryout in machines in the field (if such are available). If field machines are not available, we will submit parts to many repeated laboratory and factory tryouts prior to adoption.

At this point let us take a specific example and follow it through engineering design, material assignment, and pre-production tryout. There had been previous indications that nylon was an excellent material from which to make printing wheels. It was also indicated that certain wheels could be injection molded at a less cost than the conventional method of engraving from metal (see Fig. 1).

Investigation of the use of type wheels in a particular machine showed that the usage of different character wheels varied with customer orders. Also the wording would vary, thus making it mandatory to use certain engraved wheels interspersed with nylon wheels. Since all wheels printed at the same time, this meant that all would have to maintain accurate outside diameters. We also desired to maintain the integral driving gear dimensions and operate with tooth interference so as to eliminate wheel aligners. Knowing that nylon would

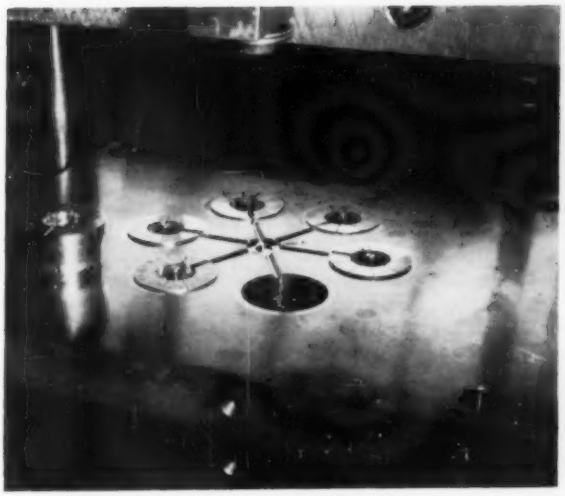

Figure 3. Production nylon type wheel mold showing cavity matrix construction and closing taper.

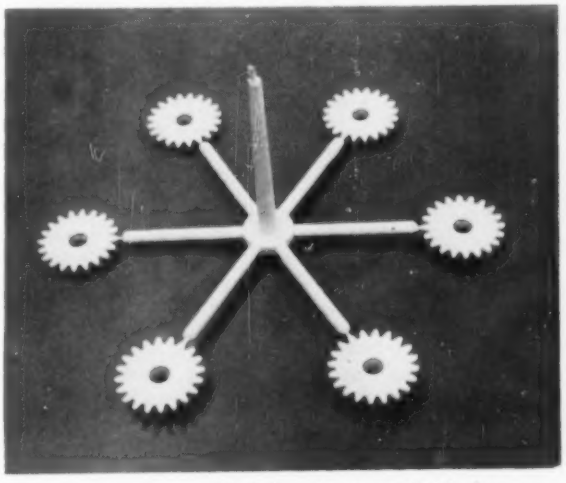

Figure 4. Injection molded shot showing individual runners from central sprue to cavities in a circle.

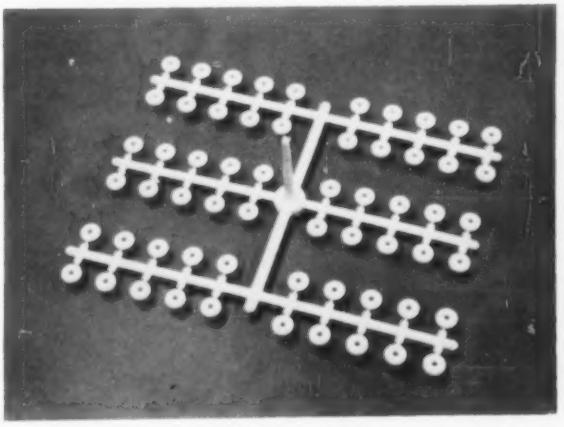

Figure 5. Injection molded shot of nylon counter wheels showing multiple branch type runners.

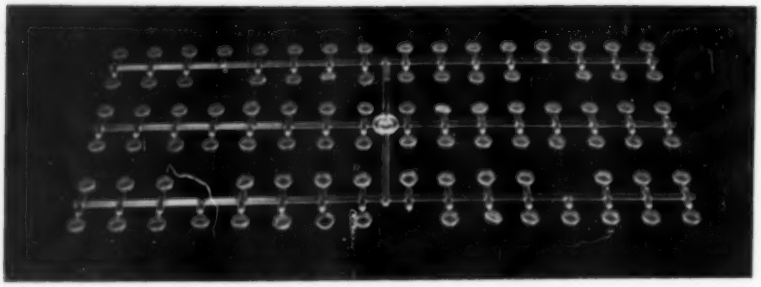

Figure 6. Injection molded shot of polystyrene caps showing multiple branch type runners.

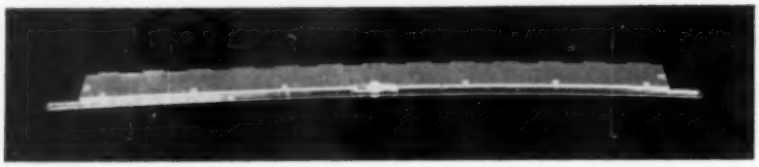

Figure 7. Injection molded acrylic part showing full length runner for edge gating.

Figure 8. Cross section of part shown in Fig. 7 showing full round runner at bottom with edge gate leading to the part above.

change its dimensions on absorption and loss of moisture, a metal insert was deemed necessary as a dimensional stability guarantee.

On the basis of the above we started off with a punched out flat metal insert which was placed in the middle of the printing section and did not extend into the smaller diameter gear section. Our first moldings showed that this was not satisfactory as the nonsupported gear section caused the entire wheel to warp toward that side (see Fig. 1—cross sectioned part at extreme left). This immediately caused us to use a machined insert which followed faithfully the finished contour of the wheel. This eliminated the warpage problem (see Fig. 1). The second items from the left are the contoured metal inserts, the third items are finished wheels, and the fourth items are cross sections of the wheels showing the embedded inserts.

One other factor which showed up in our tryouts of this printing wheel was the fact that it was necessary to maintain at least 0.030" of nylon over the sides of

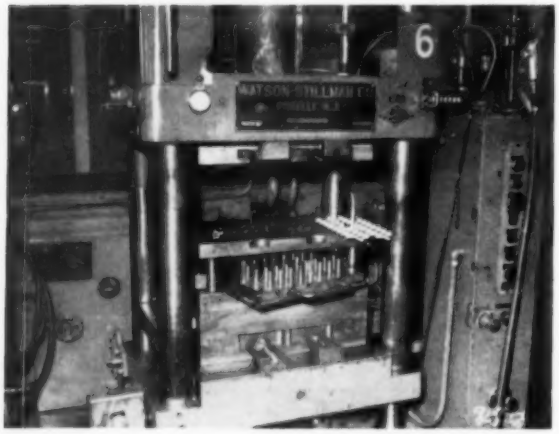

Figure 9. Double injection key tip mold of the stripper plate type. Insert loading plate is shown just below the stripper plate and a finished shot is shown resting on the stripper plate.

Figure 10. Hand-type, single cavity injection mold used in experimental work.

the inserts to prevent buckling of the nylon under high humidity conditions.

Production Planning and Tooling

Once the proper design of a part and its material assignment has been accomplished we now proceed to production planning of molds and equipment.

The first step in this planning is to determine how the mold shall be built to properly mold the part with a minimum of maintenance. With most parts this is a rather simple procedure, however, a few parts seem to make a problem of proper mold design. Let us refer back to the nylon type wheel mentioned above (Fig. 1).

The problem here was to make a circular part with projecting printing characters completely around the periphery. These characters had to have accurate radial locations and diametrical heights. The part had to be ejected from the mold with no distortion or marring of the characters.

In our first model mold we attempted to use a split engraved ring which was ejected with the molded part, then stripped off. This ring could not be held in the mold accurately enough to produce the dimensions required.

The next step (see Fig. 2) was to make a mold where each two characters had their own engraved matrix. All matrices (a ten character wheel had five matrices) were then machined and fit together with the outside being a circle. This circle then had a vertical taper machined to fit a tapered cavity. On closure, the matrices were actuated and closed by the taper to form practically a solid cavity. After the part was molded, the ejection caused all matrices to move upward and an interior circular spring caused them to move outward, releasing the projecting characters. The part could then be picked out of the mold with no interfering undercuts.

This system worked so well experimentally that it was adopted to the production mold (see Fig. 3). This mold was constructed so that each character had its own individual matrix which allows for repair or interchangeability.

The second step is to determine the number of cavities to be built into the mold. This is dependent on the following factors:

1. Yearly usage of the finished part.
2. Size of the part in area and volume.
3. Loading time of inserts (if part uses same) versus the estimated molding cycle. (Machine down time must be held at a minimum).

After the general number of cavities has been decided on, we proceed to the layout of the mold and cavities with consideration being given to the following:

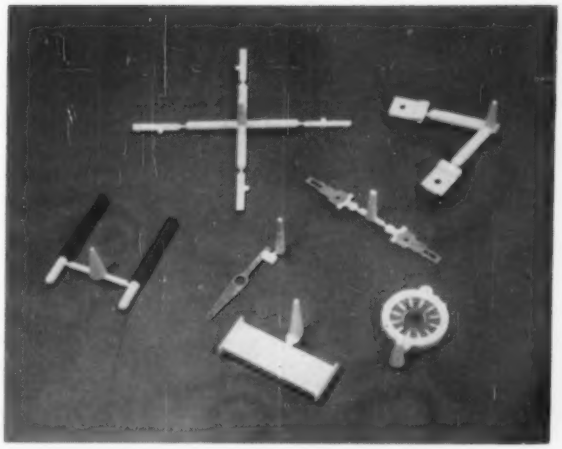

Figure 11. Injection molded specimens made from experimental hand molds.

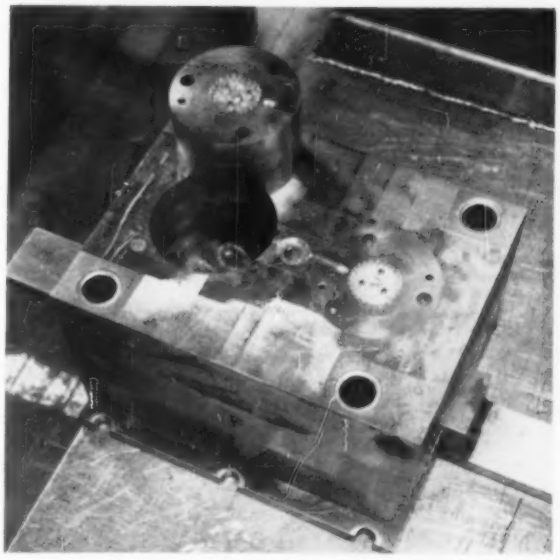

Figure 12. Two-cavity universal injection mold for interchangeable cavity inserts.

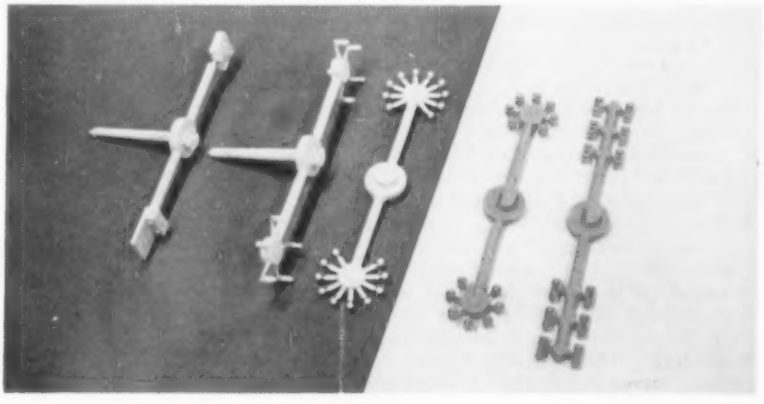

Figure 13. Several injection molded specimens from universal type interchangeable cavity.

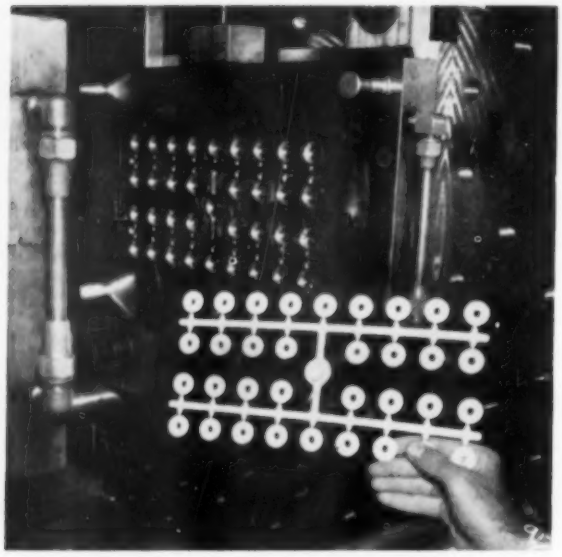

Figure 14. Large multiple cavity self-contained injection mold and molded shot.

1. If the mold is to contain only a few cavities, we attempt to place them in a circle around the sprue with individual runners to each cavity (see Fig. 4). This gives the most equal flow to all cavities.

   If a very large number of cavities are to be used, we must resort to a branch type of runner system where we have one or more main runners from the sprue with small branch runners taking off to each cavity (see Figs. 5 and 6).

   The best flow characteristics are obtained and the hottest material is delivered to the cavities through full round runners.
2. The parting line of the cavity should be placed so that the flash line does not have to be polished off for functional or appearance reasons. It should be placed so as to allow best bleed-off of air and gases in the cavity. We have found it advantageous, for instance in a gear mold, to use a cavity which has two flash lines instead of one. This eliminates a so-called blind cavity and prevents non-fill at a point which is at a different level from the gate.
3. The gate should be placed at the heaviest section, however, in some cases it may be possible to place it elsewhere such as at a non-functional or hidden surface so as to eliminate or minimize clean-up.

   With large area thin parts we have found that the broad fan type gate is best. In one instance we are using an edge gate which runs the full length of one side of the part (see Figs. 7 and 8). For heavier parts we generally use a square gate coming out of the center of a full round runner.
4. Ejector pins are generally used when a part is solid or heavy enough and pin marks do not interfere with appearance. Many parts, however, are so small or cored out to the extent that a stripper type mold is necessary. (Practically all of our key tip molds are of the stripper plate type—see Fig. 9).
5. Cooling or heating water lines must be placed in both halves of the mold in positions to provide even temperature in all cavities. We find it advantageous to use heat on our molds, particularly for acrylic and nylon. In the case of acrylic hot cavities keep strains in the finished parts at a minimum. In the case of nylon, hot molds give the finished part the proper crystalline structure for good wear resistance and eliminates the need for subsequent annealing.
6. Since the majority of our molded parts carry inserts of one type or another, most of our injection machines are of the vertical clamp construction, with six ounces being our top capacity. Inserts are, of course, a limiting factor in the number of cavities which we can place in a mold. In some cases we can circumvent this limiting factor by using pull-out-plates in the mold for holding inserts. Fig. 9 shows one of these types of molds used for multiple cavity insert work. This photo shows the pull-out-plate immediately under the stripper plate. Two or three of these plates are used per mold. While one plate carrying the inserts is in the mold, the other plates are placed on a bench for reloading and at the end of the cycle are ready to be placed back into the mold. By using this system we are not subject to machine down-time.

   Larger molds for those parts not using inserts can be placed in our larger horizontal machines.
7. We construct three general types of injection molds:
   a. One to four cavity self-contained hand molds which consist generally of only two plates with a third plate of pins used for the ejection. These molds are not fastened to the platens. Since they must, of necessity, be lightweight we use them in 2-ounce vertical injection machines. Fig. 10 shows a typical hand mold and Fig. 11 shows several parts made in this type of mold.
   b. Two to multiple (depending on part size) cavity insert universal body molds complete with internal ejection and runner system and equipped for permanent installation in four and 6-ounce machines. Fig. 12 shows one of these molds with one insert removed. Fig. 13 shows several shots from this type of mold.
   c. Multiple cavity permanent molds used only for the part for which they were designed (see Fig. 14).
8. In connection with the decision as to the construction of the mold and its number of cavities the following factors generally apply: (It should be pointed out here that factors such as size of the part in area and volume and available machine capacity also govern):
   a. If usage is less than 500 parts per year, the original model hand mold (if one was made) may be used in a 2-ounce machine for production.
   b. If usage is from 500 to 5,000 parts per year and the parts are small enough, multiple cavity inserts are made for the replacement insert universal molds.
   c. If parts are too large for multiple cavity inserts above or usage is over 5,000 per year, a self-contained permanent mold is made for the part.

Conclusion

In conclusion, we wish to point out that in business machines, A) Plastic Part Function, B) Part Design, C) Material Assignment, D) Part and Design Tryout, E) Production Planning and Tooling, require a good overall knowledge of these phases and excellent co-operation between all departments concerned.

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Saturable Core Reactor Temperature Controls

Comparative tests showed that saturable core reactor controllers cut temperature variations to 50% of that encountered on on-off time proportioning controllers, resulting in higher molding quality and lower power consumption.

George Northrop
Jamison Plastic Corp.

The custom injection molder has always been faced with the problem of maintaining high quality, low reject rates, keeping costs within reasonable limits for profitable operation. One major "sub problem" has been maintenance of uniform temperatures within the plasticizing cylinder throughout the production run with various materials.

Recent developments in the field of process instrumentation hold an economical solution to the temperature control problem.

The solution to maintenance of proper plasticizing cylinder temperature control, in our particular case, turned out to be a relatively new type of electronic device called a "saturable core reactor." It has given us a vastly improved control over temperatures during molding cycles, while at the same time reducing electrical power consumption by 14%. Molding quality can now be held consistently high, with rejects previously caused by haphazard temperature control reduced, power requirements by the heaters and hydraulic pump motor substantially reduced as well.

Here's why we put a premium on accurate temperature control:

1. If stock is injected into the mold while too cold, short shots (incomplete pieces) result.
2. If stock injected is too hot, color of the part may be affected, surface crazing may occur, and longer cycles may be required.

Figure 1. Uniform heating of plasticizing cylinder on this injection molding machine is accomplished by new saturable core reactor control.

Even if crazing is invisible, it is particularly critical on parts which we must finish later. Finishing lacquers can act through slight crazing, creating visible cracks in the finished product.

We operate over a dozen injection molding machines, ranging in size from 2 to 4, 12 and 24-ounce, with the 12-ounce unit accounting for two-thirds of our machines. In addition to custom molding, we spray, paint, decorate and assemble molded products for our customers.

Recently we added another new machine to our battery of 12-ounce units. This DeMattia machine was chosen as the production "temperature control test" machine. It was provided with Wheelco saturable core reactor temperature controls for the plasticizing cylinder. We've kept close track of the performance of the machine to observe whether this new instrumentation made any appreciable difference on our production. We've accumulated enough experience to be convinced that the installation resulted in definite improvements in quality and control.

Equipment and Modifications

The plasticizing cylinder on our new machine has a $2\frac{3}{4}$" diam. injection plunger with a stroke of $11\frac{1}{2}$ in. Hot plastic enters the runner at 22,500 psi with maximum plunger forward stroke rated at 115 ipm. This machine handles a mold 18 in. by 30 in. Closing ram pressure of 5000 psi, results in closed mold locking pressure of 400 tons.

Rated capacity of the machine is 130 lbs./hr., with a maximum production of 240 shots/hour (4 cycles/minute). We run it at a rate anywhere from 20 to 200 shots/hour, depending on: (1) the plastic; (2) the part being molded.

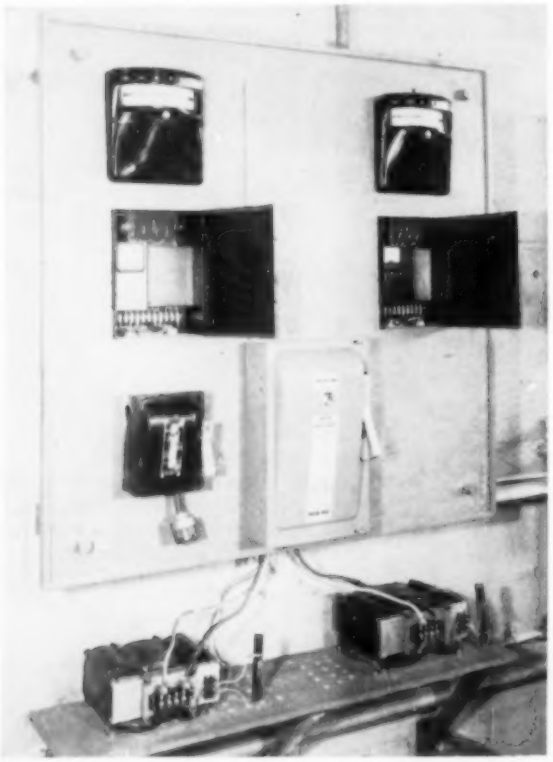

Figure 2. Closeup of control panel showing instruments used in cylinder temperature control. Cover over saturable core reactors (bottom) is removed and doors of pilot amplifiers (on panel) are also open to show interiors.

Plastics most commonly used are styrene, acrylic, and nylon (540°F, 450°F, and 650°F respectively), as well as critical pastel colors, and heat-sensitive special colors.

Two heating zones, separately controlled, are used for the plasticizing cylinder. Three Calrod Heaters, totaling 10 kva, are used for the rear (feed) zone (one 4-kva and two 3-kva heaters). The front (nozzle) zone has 2-kva heaters. Another 2-kva heater is used where the cylinder necks down to nozzle diameter. One 0.5-kva heater is used on the nozzle itself.

To maintain 550°F at the rear zone, we have installed a Wheelco Model 407 Capacitrol with a 610 pilot amplifier and a 10-kva saturable core reactor, series wound for 220-v operation. To maintain 540°F at the nozzle, we used a Wheelco Model 407 Capacitrol with a 6.5-kva saturable core reactor.

A third instrument may be added later, if desired, for separate control of the nozzle temperature (the 0.5-kva heater). Results to date indicate that this will not be required unless unusual changes in molding or raw material take place.

Tests and Results

To determine any inrcease in efficiency resulting from the installation of these new controls, we ran short but thorough tests comparing performance of the new, saturable core reactor controllers versus conventional on-off time proportioning controllers.

We found that stock temperature variations were cut in half when saturable core reactor control was used.

We noted that the injection plunger moves through the plasticizing chamber at a more uniform speed when temperature is consistently maintained throughout. Both the distance traveled and speed itself are subject to greater variation when "anticipating" on-off controls were used.

As a result power peaks were substantially reduced. The combination of lower power peaks and reduced motor requirements (due to lowered plunger friction) cut total power needed by 14%. For the test, we used a three-plate mold of 12 cavities for a total shot of approximately $5\frac{1}{2}$ ounces.

The use of the saturable core reactor control system eliminated all tendency of parts to stick in the cavity. We are now also experiencing the same benefit in our regular production runs. This confirms the findings of one of the major materials suppliers: as much as 25% increase in cavity pressure can result from a 20°F increase in stock temperature. This condition could result in the occasional sticking experienced with the less precise temperature control methods.

Our experience with saturable core reactor temperature controllers proves to us the value of modern molding equipment provided with instrumentation of advance design. The need to meet increasing competition, as well as the desire to improve product quality, have made the installation a good investment.

The Calrod Heaters used on this equipment have seen uninterrupted operation 24 hours a day for the past three years. Up to this point, no heater repair or replacement has been necessary. The savings resulting from lack of downtime and the increased production have more than paid for the additional cost of these saturable core reactor control systems.

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A Quick Test for Carbon Black Dispersion

The curves recorded on a simple microdensitometer can be analyzed statistically to give a precise measurement of carbon black dispersion in polyethylene.

W.G. Best and H.F. Tomfohrde, III
Union Carbide Plastic Co.
Development Department

Most of the polyethylene being used in outdoor jacketing applications contains a dispersion of carbon black for protection against ultra-violet irradiation. Maximum protection against this destructive element is governed by both the degree of dispersion and the type of carbon black employed. A great deal of effort has been directed towards the development of reliable testing methods for determining the degree of dispersion of carbon black. These methods include the Bell Laboratories' qualitative microscope examination, white light absorption, ultra-violet light absorption, electron microscope examination, and the Photovolt Transmission Densitometer techniques described by Schulken, Newland and Tamblyn (Ref. 1) at the Sixth Annual Wire and Cable Symposium. The development of a reasonably precise microddensitometer and mathematical treatment of resulting data at Union Carbide Plastics Company (Ref. 2) has enabled the study of carbon black dispersion by this method.

This paper presents the work performed to date at Union Carbide Plastics Company and points out limitations and areas where improvement of the techniques

This paper was presented before the Seventh Annual Wire and Cable Symposium at Asbury Park, N.J.

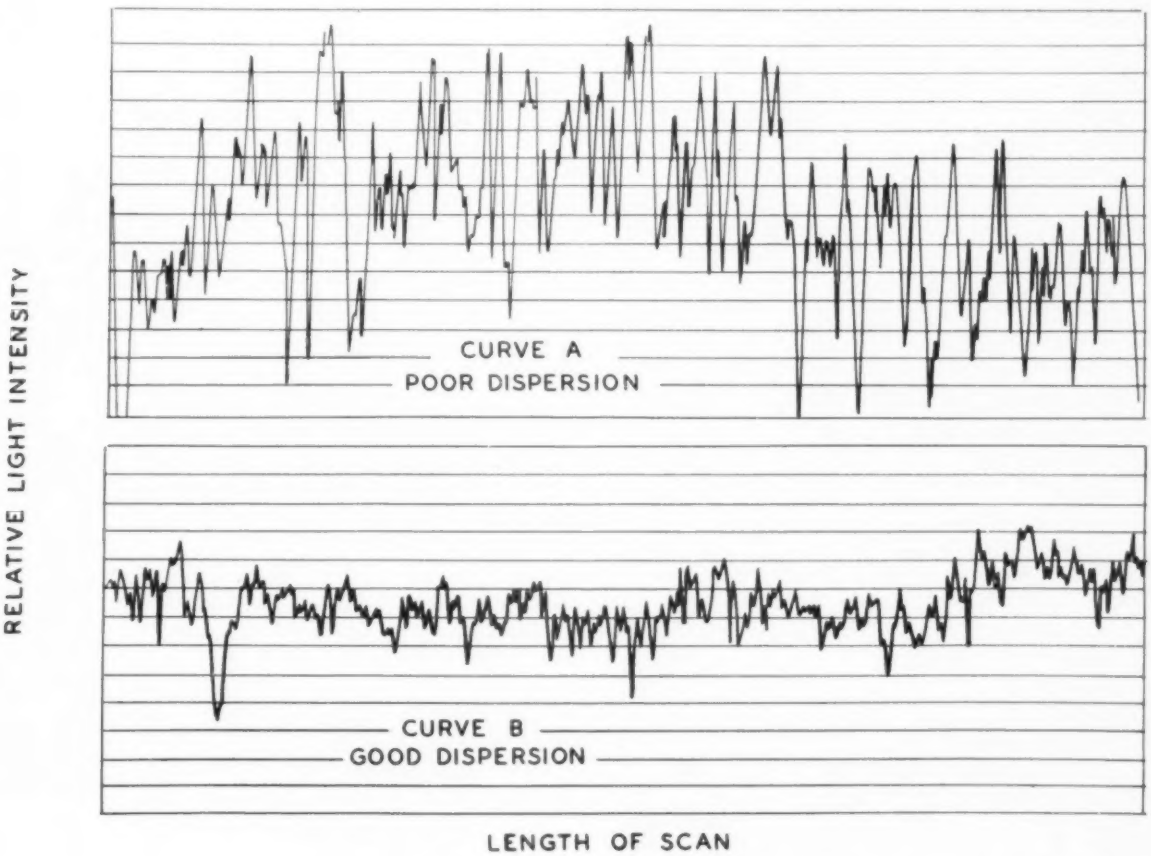

Figure 1. Dispersion patterns for two samples of carbon black in polyethylene.

TABLE I

Sample No.	1A	1B	2A	2B	3	4	5	6
Bell Lab's Microscope Rating	B+	B+	D	D	B+	B+	D	C
Ultra-Violet Absorption, Coefficient x 10^{-3}	—	—	—	—	11.7	16.0	27.6	11.5
Coefficient of Variation (calculated from micro-densitometer data)	2.22	2.10	4.38	6.52	2.90	2.94	4.75	3.55

Note: 1A, 1B and 2A, 2B are duplicate determinations.

employed is desirable. Since a wealth of information has already been published on the effect of dispersion on weathering, we feel that this area is outside the scope of this paper.

DISCUSSION

Test Method

The equipment used in this testing method consists of a simple microdensitometer mounted on an optical bench. A finely focused beam of white light 10 microns in diameter scans the test specimen. This intense micro-spot of light is viewed by a sensing microscope at a magnification of 100 diameters. A specimen prepared in the form of a thin film 1 mil thick is scanned by moving it in a direction normal to the light path. Variations in carbon black dispersion result in variations in the optical density of the transmitted beam which falls on a photomultiplier. The output of the photomultiplier is amplified and then fed to a suitable recorder. Good and poor dispersions result in curves similar to those shown in Fig. 1.

Upon recording of the dispersion results, the curves are analyzed statistically in the following manner. A grid representing increasing relative light intensity is placed over the recorded curve parallel to the abscissa and the number of times the curve passes through each marked light intensity line is counted. These data are then plotted as frequency of occurrence versus relative light transmitted. This results in the distribution curves shown in Fig. 2. The distributions which have been described lend themselves to a statistical analysis of variation as described by Hoel (Ref. 3). The first moments of the distribution result in the mean and the second moments result in the standard deviation.

It is readily apparent that the degree of dispersion will determine the shape of the distribution curve and therefore meaningful numerical values can be assigned which accurately describe the distribution. The described technique has been applied to several samples of polyethylene containing approximately 2.6% of Monarch 74 carbon black.

Test Results

The data obtained from dispersion patterns of several polyethylene samples are shown in Figs. 3, 4 and 5. The patterns from which this information was obtained were similar to those illustrated in Fig. 1. As can be seen in Figs. 3 and 4, where duplicate determinations were made, the ability to reproduce the microdensitometer technique proves satisfactory. Poorer reproducibility using a poor dispersion would be expected due to the heterogeneity of the specimen. Fig. 5 graphically illustrates the distributions for two additional samples.

The appropriate statistical analysis was made for

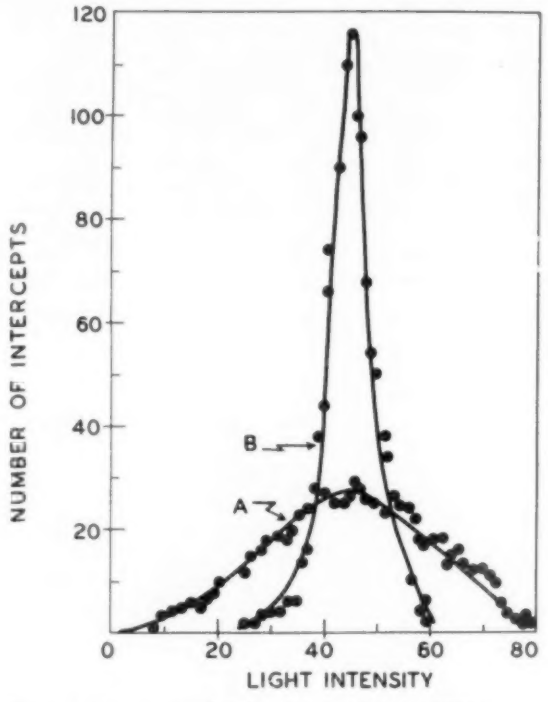

Figure 2. Frequency distributions of light intensity.

these distributions and the data compared with other methods of evaluation. The results are found in Table I.

Comparisons with the microscope rating of dispersion and ultra-violet absorption techniques indicate that the microdensitometer and resultant statistical analysis will describe the degree of carbon black dispersion in a manner similar to existing methods. The microdensitometric approach to the measurement of carbon black dispersion offers much potential as a fundamental, time-saving approach capable of being effectively reproduced. While the present equipment, consisting of an optical bench type of set-up, restricts the degree of precision obtainable, microdensitometers have been constructed in which excellent precision has been obtained. Altman and Stultz (Ref. 4) of the Kodak Research Laboratories report a resolution of 1800 lines per millimeter with their equipment. Such a resolution could conceivably enable the differentiation between carbon black agglomerates, "pepper" type of dispersion and gel spots in addition to greatly improved precision and reproducibility. The present methods of analysis result in an independent measurement of carbon black

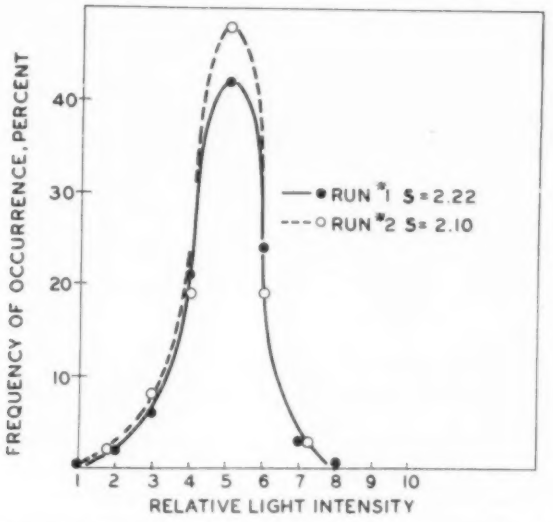

Figure 3. Reproducibility of microdensitometer test sample No. 1, good carbon black dispersion.

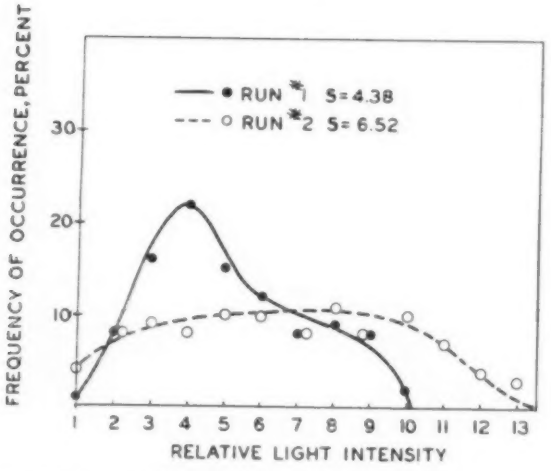

Figure 4. Reproducibility of microdensitometer test sample No. 2, very poor carbon black dispersion.

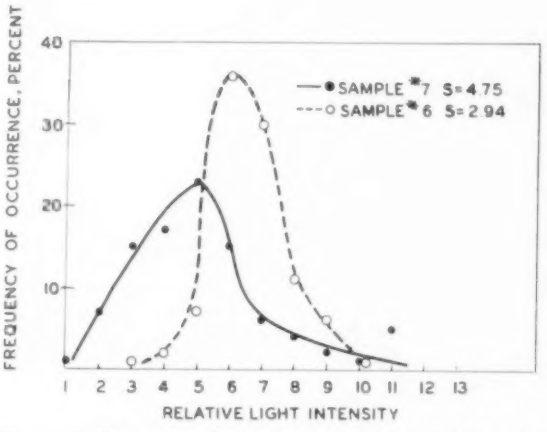

Figure 5. Illustration of good and poor carbon black dispersion microdensitometer measurement.

agglomerates, dispersion and gel spots. Using the microdensitometric technique, the evaluation of these three properties can be combined into a single number which results in a weighted average of those properties.

Modifications of the microdensitometer are possible so that both translational and rotational movement of the specimen would be possible. This could increase the sample size several orders of magnitude over that of the microscope test. If this increase in scanning area could be accomplished at high speeds, then the voltage signal of the photomultiplier could be fed into an electronic circuit and the voltage analyzed in two parts, A-C and D-C. This in effect is an electrical integration which is now mechanically performed and which was previously described in this paper. This method could be used to complete a statistical index of dispersion.

CONCLUSION

This paper has briefly described a method and apparatus for the measurement of carbon black dispersion in polyethylene. This work illustrates a potential method which is free of empirical influences, more reliable and precise, and less time consuming. The testing thus far indicates that with more precise instrumentation it should be possible to measure carbon black dispersion and gels independently and to determine, electronically, a dispersion index. It is hoped that this technique will be evaluated by others to better establish its practicability as a *standard* for measuring carbon black dispersion.

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How to Reduce Carbonization in the Injection Cylinder

Molders using polyethylene are at times plagued with abnormally high reject rates due to carbon specks in their parts. Although there has been some information published on the subject, much of it has either been vague or required new heating cylinders. In order to develop more specific information using conventional equipment, the degradation of several polyethylenes was studied in a representative 4-oz. injection press. It was learned that several proper preventive maintenance steps might minimize this oxidative degradation with a corresponding reduction in scrap loss.

C. S. Imig

Spencer Chemical Company
Sales Service Laboratory

HIGH MELT INDEX polyethylenes have gained tremendous acceptance in the field with their ease of molding, faster cycle time and improved surface. Soon molders, however, learned that they occasionally encountered delamination of the articles which luckily was quite easily remedied by adjusting the machine conditions, primarily the injection temperature. Molders using these high melt index materials soon noticed black specks in their moldings and were unable to eliminate them. In some cases rejects due to these black specks ran as high as 80%. The molders were unable to pinpoint the source of their trouble but felt that they were able to minimize the rejects by a change to a different lot of material, either from the same or a different supplier. In some cases it was noted also that the same lot of material would give an erratic behavior—running well on one day, but then not on another. In order to shed more light on the subject and possibly be of as-

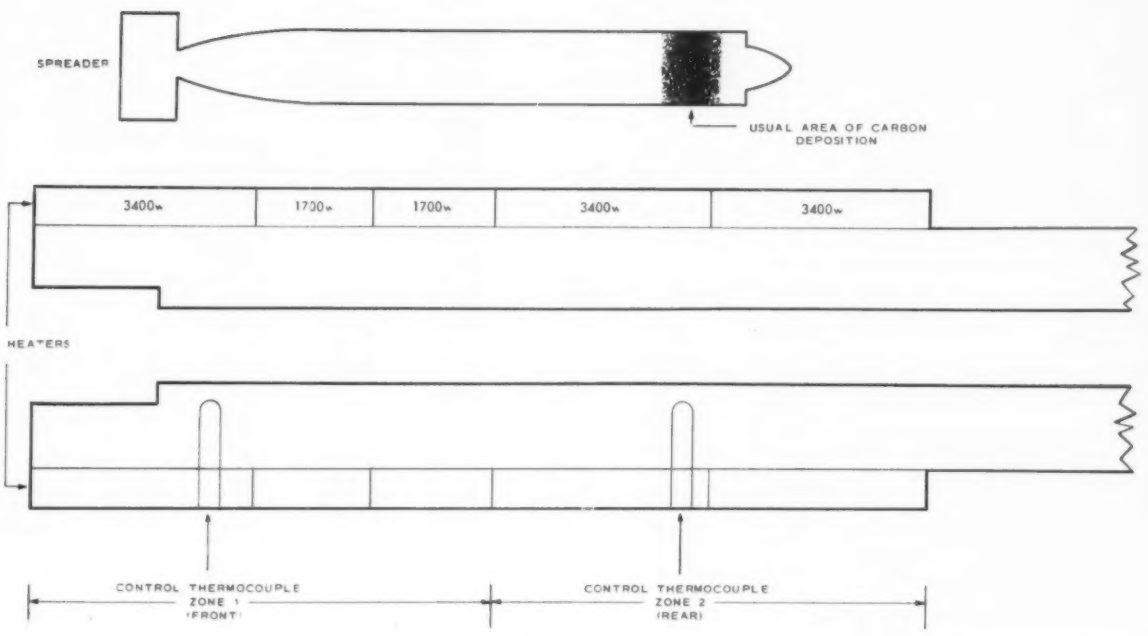
TABLE I

Examination of Moldings

Resin	Melt Index	Total Cups	Amount Good		Amount with Specks		Amount Skinned	
			Number	Percent	Number	Percent	Number	Percent
				Seven Day Runs				
A	22	18,591	17,528	94.0±0.6	1002	5.4±0.9	61	0.3±0.1
B	22	17,695	16,277	92.0±1.4	1396	7.9±1.4	22	0.1±0.1
				One Day Runs				
A	22	2598	2450	94.3	147	5.6	1	0.1
A + CO_2	22	2614	2494	95.4	120	4.6	0	0
C	22	2675	2498	93.4	171	6.4	6	0.2
E	22	2694	2307	85.6	387	14.4	0	0
F	10	2524	2356	93.4	158	6.0	9	0.6
G	17	2646	2400	90.7	245	9.2	1	0.1
H	22	2510	2379	94.8	130	5.1	1	0.1
				Four Hour Low Temperature Run				
A	22	431	406	94.3	25	5.7	0	0

FIGURE 1

EXPLODED CROSS SECTION OF THE HEATER



sistance to the molder, the following work was undertaken at Spencer Chemical Company's Sales Service Laboratory.

Results

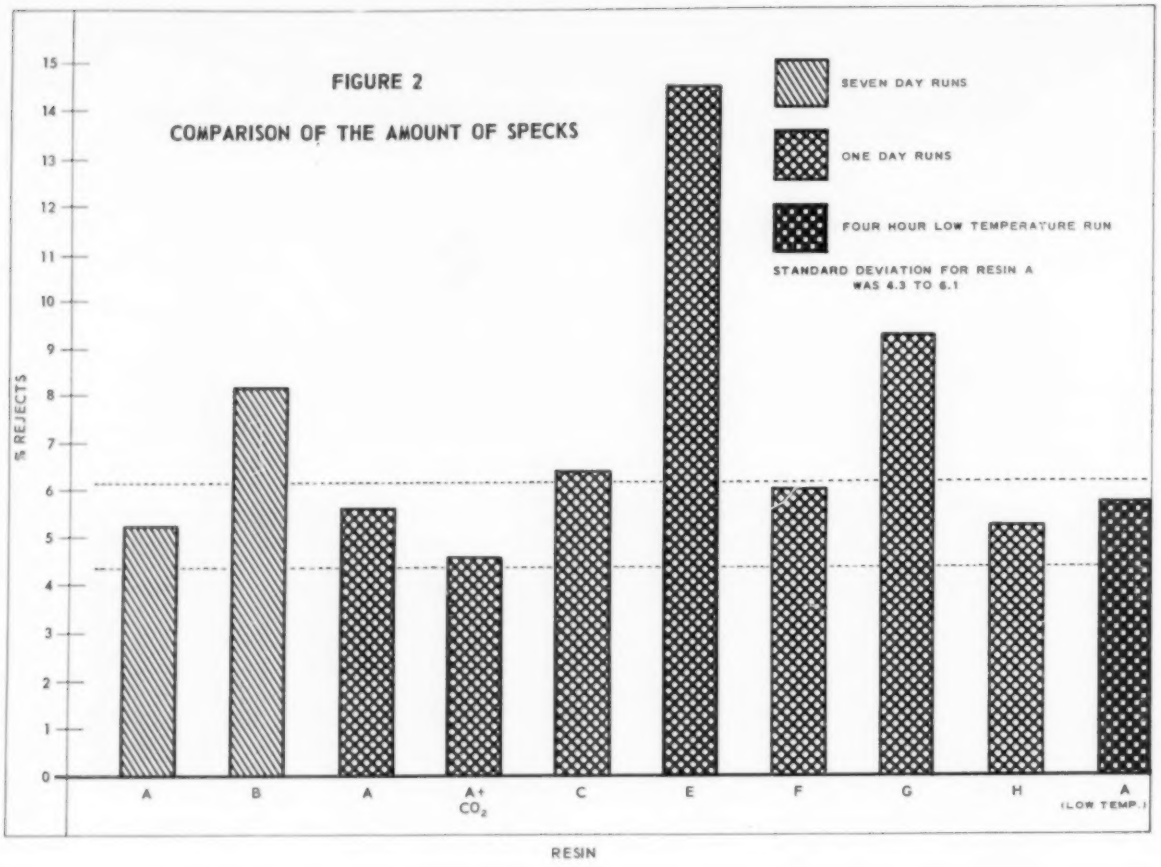
This study was carried out on a 175T 4/6-oz. Reed-Prentice injection press using an 8-oz. tumbler mold. Cylinder temperatures of 475°F, rear, and 525°F, front, were used with a mold temperature of 70°F, injection pressure of 10,000 psi and overall cycle of 30 seconds. Each molding was examined critically for delamination (or skinning) and black specks. A cleaned cylinder and spreader was used each time a different resin or technique was evaluated. All resins were low density materials.

The results are summarized in Table I. In a continuous seven day run, 18,591 cups were molded from resin A. Of these, 94% were judged satisfactory, 5.4% rejected because of black specks and 0.3% rejected due to skinning. The number of rejects due to specks varied all the way from 3.1 to 8.2% for a given 8-hour period while the standard deviation was ±0.9%. The number of rejects due to skinning was considered negligible. Resin B yielded 17,695 cups with 91.8% satisfactory, 8.1% rejected because of specks and 0.1% rejected due to skinning. The rejects due to specks varied from 5.1 to 15.9% for a given 8-hour period while the standard deviation was ±1.4%. Samples were retained periodically throughout these runs for melt index, yield strength, tensile strength and elongation determinations. No variation in these physical properties was detected for either resin throughout the run. Examination of the dismantled cylinder after each run revealed that carbonization had taken place at the rear of the spreader. This area is shown in Fig. 1. Resin B showed more carbonization than resin A.

In order to expedite the evaluation, we attempted to correlate one-day evaluations with the seven-day evaluations. These results are also shown in Table I. Resin A was rerun and the results were seen to correspond to those obtained previously. Examination of the spreader revealed carbonization as before but to a much lesser extent. To verify the theory that oxygen was essential to the carbonization, resin A was again run using an inert blanket of carbon dioxide over the pellets as they were fed into the cylinder. The amount of rejects due to specks decreased somewhat but not to a significant extent. It was very significant, however, that there was no trace of carbonization or even discoloration anywhere in the cylinder.

Since it is often quite difficult to correlate results done in the laboratory to results in the field, resin C on which we had some field experience was compared to resin A. The amount of rejects was just barely higher than obtained with resin A. The appearance of the spreader was comparable. Resin E with added antioxidant was a great disappointment displaying a greater number of rejects and more carbonization and discoloration in the cylinder.

Resins F, G and H, having melt indexes of 10, 17 and



22 were evaluated to see the effect of melt index on this carbonization. The intermediate melt index resin displayed the most rejects and somewhat more carbonization on the spreader. The difference was no more than between resins A and B of the same melt index.

To show the effect of molding temperature resin A was run for four hours using the minimum possible molding temperature, 275°F. The amount of rejects was similar to the higher temperature results but no carbonization was detected on the spreader.

Discussion

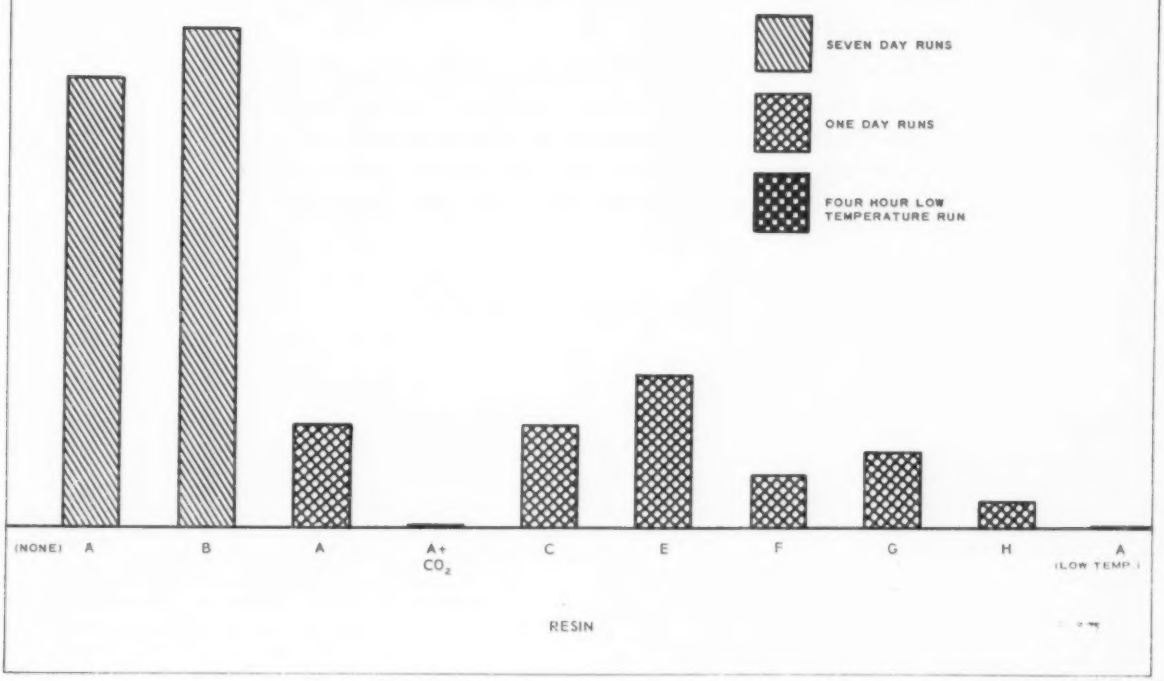
All the data obtained on the number of rejects and appearance of the heater are summarized in Figs. 2 and 3. Let us concern ourselves first with the amount of rejects for the different materials. Within the accuracy determined on the 7-day run of resin A, none of the resins showed a significant trend toward a lower number of rejects. However, resins E and G gave an appreciably higher number of rejects while the number of rejects for resin C were just barely above the precision of the determination. This would lead one to believe that the majority of these specks appearing in the moldings were the result of contamination picked up during the molding operations somewhere. It is difficult to see how more than a small percentage was due to carbonization of the material in the cylinder except possibly in the case where the number of rejects ran as high as 10% or more.

Because of this possible interference of contamination with carbonization it appears that our best criteria is the appearance of the spreader after molding as shown in Fig. 3. As may be seen, the melt index 22 resins, A and C run in the usual manner showed a comparable degree of carbon deposition on the spreader indicating that all were quite similar. The material with added antioxidant, resin E, showed an added amount of deposition indicating that the antioxidant certainly did not decrease the amount of carbonization and most likely increased it. Resin A molded both under an inert atmosphere of carbon dioxide and at minimum cylinder temperature showed no trace of carbonization in the cylinder whatsoever. This verifies the theory that oxygen and heat were essential for the carbon deposition. Stock temperature required to induce this carbon formation would have to fall somewhere above 280°F. Resins F, G and H prepared in a similar manner but having different melt indexes produced erratic results as in the examination of the mouldings. All materials showed less carbonization than resin A. However, none of the cylinders were as clean as those of the inert atmosphere or low temperature runs. These erratic results indicate that there is no relationship between melt index and the degree of carbonization with the range of melt indexes studied.

Conclusions

Of all the different resins tested, none successfully eliminated carbonization in the cylinder although some displayed noticeable improvement over others. The susceptibility to carbonize had to be measured by actual examination of the inside of the heating cylinder since

FIGURE 3
COMPARISON OF CARBON DEPOSITION ON THE SPREADER



most of the black specks in the moldings were directly attributed to some sort of contamination picked up in the molding process. Since there was as much variation in the amount of rejects due to black specks between different shifts as there was between the different resins or lots of resin, one cannot trace the source of the specks to a given lot or a given resin. Since most of the specks in the moldings were not directly attributable to carbonization of the material in the cylinder it points out that one may allow a certain degree of carbon build-up before it will begin to flake off and show up in the moldings. It was shown, also, that at least one anti-oxidant was ineffective in preventing carbonization.

In addition to the above, some insight was gained concerning this phenomena of carbonization of polyethylene in the heating cylinder. By the use of minimum possible operating temperatures it was established that a certain minimum amount of heat is required for the carbonization to take place. Of course, this information is not particularly useful to the molder since the temperatures employed were generally considerably lower than what would normally be possible for him to use. Also, by maintaining inert atmosphere of carbon dioxide over the injection cylinder, it was established that the presence of oxygen was vital to this carbonization. Although at first it might seem quite unlikely that this would be of any practical use to the molder it is possible he could do much the same as we did in maintaining an inert atmosphere in the injection cylinder. Carbon dioxide is preferable over something like nitrogen since it is heavier than air and as a result should provide a more effective blanket. When setting up an installation such as this, care must be taken to provide gas tight enclosures around the feed area as much as possible to minimize the volume of gas required to completely flush the air from the incoming pellets.

From what we have learned there are also two other ways which will not completely eliminate carbonization but should minimize the number of rejects resulting from the carbonization. The first is allowing the press to stand with the heat set at about 250° to 300°F when it is not in operation. This practice minimizes thermal expansion and contraction of the heating cylinder and should reduce the tendency for the carbon deposits to flake off on subsequent start-up. This procedure should materially reduce the number of rejects on start-up (when the greatest number of rejects generally occur) but its long range benefit is not clear cut. Second, and more beneficial, is the regular practice of purging the machine both on start-up and shut-down to both scrub the cylinder and aid in lowering the cylinder temperature and thus avoiding possible polymer degradation. If the press is kept running for very long periods of time it is recommended that periodic purging be done possibly as often as once or twice a week. The frequency of course, should be determined by experimentation by the individual molders. For the usual high melt index molding grade polyethylenes, high density low melt index polyethylenes have proven to be very effective, even though expensive, purging compounds. These polyethylenes have the advantage that you don't have to reduce materially temperatures to get effective purging action. In one case, purging at 400° to 500°F with a melt index 1, 0.935 density polyethylene reduced the reject rate from about 5% to almost nothing for the several days that we followed the problem.

★ ★ ★

DEGRADATION OF CELLULOSE ACETATE FILMS

A study made on several commercial films showed that they varied widely in their stability. For highest stability, plasticizers containing an aliphatic ether linkage should be avoided and acid acceptors and anti-oxidants should be incorporated into the film formulation.

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Introduction and Review of Literature

Laminating film made from cellulose acetate is used by many archival agencies for the repair and reinforcement of weak or damaged documents.

The data reported in this paper were obtained mostly on film formulations that could be considered useful for repair of archival documents by lamination. A laboratory aging procedure for testing archival film has been developed, and used to compare the stability of various commercial and experimental films.

Although considerable information has appeared in the literature on the laboratory degradation of cellulose acetate, little of this work has been concerned with actual film formulations. Evans and McBurney (Ref. 1) studied the degradation of several cellulose acetate flakes at 160°C. The rate of degradation was followed by measuring the oxygen consumed and by determining the intrinsic viscosity of the residue. Many samples exhibited an induction period during which little or no degradation occurred. A plot of oxygen absorbed against intrinsic fluidity (reciprocal of intrinsic viscosity) gave a straight line, and they suggested that intrinsic fluidity is a measure of chain breaks that occurred during degradation. The degradation at 160°C was essentially oxidative in nature and appeared to be a function of the oxygen concentration. Carbon monoxide and carbon dioxide were produced.

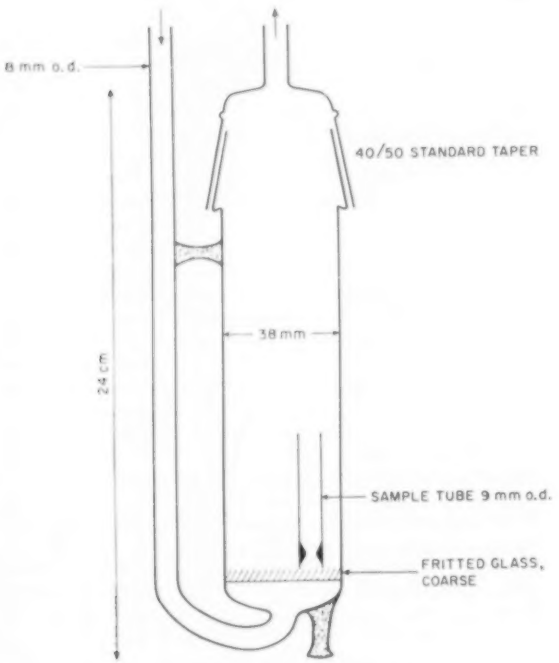

Figure 1. Aging vessel and specimen holder.

Biggs (Ref. 2) has reported that oxygen may be consumed by cellulose acetate butyrate at elevated temperatures without an appreciable decrease in viscosity.

DeCroes and Tamblyn (Ref. 3) have reported that the plasticizer in cellulose-ester plastic systems is often the chief contributor to degradation, and that most of the common plasticizers were more easily oxidized than the cellulose ester. Oxidation was the chief cause of degradation at 150°C, but some decomposition also occurred under nitrogen. The oxidative degradation could be accelerated by the addition of peroxides.

Schreiber, Bullock and Ward (Ref. 4) found that partially acetylated cotton was much more resistant to degradation by air containing nitrogen dioxide or hydrogen chloride than untreated cotton. From this, it would appear that cellulose acetate is more stable toward some degrading influences than is cellulose itself.

McBurney (Ref. 5) has discussed the degradation of cellulose derivatives on the basis of their solubility in water or in nonaqueous solvents. The water-soluble derivatives are usually less completely substituted and the stability is usually more nearly like that of cellulose itself. The derivatives that are soluble in organic solvents are, in general, more completely substituted, and the stability is influenced to a greater extent by the substituent group.

Homogeneous hydrolytic depolymerization of cellulose acetate appears to be random, and this reaction has a larger activation energy than the deacetylation reaction (Ref. 5). Therefore, hydrolytic depolymerization is more temperature-dependent than is deacetylation.

Doyle (Ref. 6) has applied the superposition principle to data on the heat-aging of plastics. By the use of Arrhenius plots or Arrhenius rate equations, factors are

TABLE I

Cellulose Ester Flakes Used in the Degradation Studies

Sample No.	Degree of Substitution	Acetyl	Propionyl	Butyryl	Viscosity[1]
		%	%	%	sec
		Cellulose Acetate			
A	2.44	39.7	—	—	51[2]
B	2.68	42.0	—	—	165[3]
C	2.34	38.4	—	—	41[2]
D	2.41	39.3	—	—	69[2]
E	2.38	39.0	—	—	80-110[4]
F	2.39	39.2	—	—	100-120[4]
G	2.49	40.1	—	—	23[5]
H	2.41	39.4	—	—	30[5]
I	2.40	39.3	—	—	44[5]
J	2.41	39.4	—	—	62[5]
		Cellulose acetate propionate			
K	2.69	30.0	14.0	—	75[5]
		Cellulose acetate butyrate			
L	2.61	12.9	—	36.9	31[5]
		Cellulose propionate			
M	2.75	—	—	—	80-110[4]

[1]Manufacturer's data.
[2]ASTM D871-48, formula A.
[3]ASTM D871-48, formula C.
[4]Viscosity at 25°C of 6 grams of cellulose acetate in 100 ml of a mixture of 95 grams of acetone and 5 grams of water measured by ASTM ball-drop method, D1343.
[5]ASTM D1343-54, formula B.

calculated which make it possible to translate the data from several aging temperatures into one master aging curve at a single temperature of interest.

A comprehensive investigation of the weathering of various plastics has been reported by Barrett (Ref. 7). Cellulose acetate formulations covered a wide range in strength properties, from little loss to over 50% loss over a period of 2.5 years.

Yustein, Winans, and Stark (Ref. 8) exposed various plastics, including cellulose acetate, in various test areas in North and Central America. Atmospheric contamination appeared to be the most important factor in the deterioration of cellulose acetate.

Samples Studied and Methods of Analysis

Cellulose esters.—The samples of cellulose esters used in this study included (a) several commercial films of cellulose acetate and cellulose acetate butyrate, (b) flakes of cellulose acetate, cellulose acetate propionate, cellulose acetate butyrate, and cellulose propionate, and (c) several experimental formulations made with these flakes and various plasticizers. The commercial films are identified by number only, 4 through 14. The cellulose ester flakes are described in Table I. The experimental-film formulations are described in the tables and figures presenting the aging data.

Plasticizers.—Several different plasticizers, mostly of the active solvent type, were used in making up the cellulose acetate formulations. The refractive index and specific gravity of the samples of dimethyl phthalate, diethyl phthalate, and dimethoxyethyl phthalate, and the melting point of the triphenyl phosphate were found to be very close to the recorded values. Data from the plasticizer-quality test of Malm, Genung and Townsend (Ref. 9) are given in Table II for a few plasticizers.

Apparatus for laboratory aging at elevated temperatures.—An apparatus was built that allowed aging of cellulose ester specimens at temperatures up to about 180°C in various atmospheres. Oxygen, nitrogen, or air was passed continuously over the specimens at a rate of about 50 ml/min., with provision for moistening the gas by bubbling through water held at a constant temperature.

An oil bath, consisting of a stainless-steel beaker (8-liter capacity) set in an electric heating-mantle in an aluminum housing, was used for most of the aging experiments. A diagram of the aging vessel and specimen holder is given in Fig. 1. The aging vessel was made by sealing a coarse, fritted-glass funnel to an inner $\frac{40}{50}$ standard taper joint. The specimen holder was a glass tube about 4 cm long, 9 mm O.D., constricted slightly at the bottom. The film was loosely rolled, before it was placed in the specimen tube. The temperatures recorded in the tables were determined by inserting a thermocouple into the reaction vessel in the vicinity of the specimen tube.

Intrinsic fluidity.—Degradation rates of various films were evaluated by comparing the slopes of the plots of intrinsic fluidity against time (in days). The cellulose acetate specimens were weighed before the aging experiment, and allowance for plasticizer and moisture content was made. After the aging period, the viscosity at 1/4, 1/2, and 1% concentration in 9 parts of methylene chloride plus 1 part of methyl alcohol, by weight, was measured at 20 ±0.1°C. Intrinsic viscosity[1] was obtained from a plot of $\log \frac{\text{specific viscosity}}{\text{concentration}}$ against concentration. An Ubbelohde suspended-level viscometer, covering the range 0.5-2.5 centipoises, with a reservoir of about 100 ml, allowed dilutions to be made in the viscometer.

As might be expected, the reproducibility of fluidity measurements was much better on unaged specimens

[1]The density of the viscosity solvent was 1.247. The intrinsic fluidity values in the tables can be converted to units based on grams of solute per 100 ml of solvent by multiplying by 1.247.

TABLE II

Plasticizer Quality as Indicated by the Eastman Kodak Test[1]

Plasticizer	Appearance of Filter Paper after One Hour at 177°C
Dimethyl phthalate	No discoloration
Diethyl phthalate	Slight discoloration
Diethyl phthalate plus crystal of magnesium acetate	Slight discoloration
2,2-Dimethoxyethyl phthalate	Very light brown
2,2-Dimethoxyethyl phthalate plus crystal of magnesium acetate	Very light brown
Triphenyl phosphate	No discoloration

[1]A strip of filter paper was partly immersed in a few ml of the plasticizer in a test tube clamped in an oil bath maintained at 177°C. Depending on specific experimental conditions, the extent of discoloration of the filter paper is an indication of the purity of the plasticizer.

than on aged specimens. For 28 pairs of duplicates, the standard deviation for agreement between duplicates was 0.0124 for the unaged specimens. For the aged specimens, the standard deviation, for 40 pairs of duplicates taken at random, was 0.08. Agreement between duplicates was much better in the early part of the aging period.

Plasticizer content.—Plasticizer content was determined by the method of Whitnack and Gantz (10).

Preparation of films.—Experimental films were cast on glass plates from a solution of 10 grams of flake plus plasticizer in 90 ml of acetone plus 10 ml of methyl alcohol. Some of the films were washed in distilled water at 60°C for 10 minutes to remove solvent, and others were vacuum-dried at room temperature.

Stress-strain measurements.—Tensile stress-strain data were obtained with a constant-rate-of-straining machine. The initial jaw-separation was 4 inches and the rate of motion of the cross head was 2 inches per minute. Specimens were prepared with a film cutter, and the edges of representative specimens were examined under a microscope for imperfections.

Thickness of films.—Thickness of films was determined by TAPPI Standard T411.

Degradation in air containing hydrogen chloride or nitrogen dioxide at room temperature.—Using the general procedure of Schreiber, Bullock and Ward (Ref. 4), specimens were exposed to air containing hydrogen chloride at concentrations of 1.16% and 0.12% by volume, in vacuum desiccators at 25° C and 50% relative humidity.

Film specimens were exposed to air containing nitrogen dioxide in a jar of 18-liter capacity having a rotating sample-rack.[2] The nitrogen dioxide was metered into dry air, and this mixture was then mixed with moist air, to give an atmosphere containing 0.2% of NO_2 at about 45% relative humidity at room temperature. This atmosphere was renewed at a rate of about 18 liters per minute.

Results and Discussion

Degradation of representative unplasticized and plasticized films.—Two films were selected for intensive study—a plasticized film (Film No. 4) and an experimental unplasticized film cast from a cellulose acetate flake (Flake D in Table 1). The change in intrinsic fluidity of the plasticized film with time was studied at temperatures ranging from 60°C to 177°C, and the unplasticized film was studied at temperatures ranging from 110°C to 176°C.

As long as an atmosphere of the gas being used during a particular aging experiment surrounds the speci-

[2]The exposures to nitrogen dioxide were made through the courtesy of John Gustafson of the Textiles Section, National Bureau of Standards.

TABLE III

Effect of Rate of Flow of Oxygen[1] on the Degradation Rate of Cellulose Acetate Film No. 4 at 124°C.

	Low Rate of Oxygen Flow			High Rate of Oxygen Flow		
Time	Rate of Flow of Oxygen	Intrinsic Fluidity	Weight Loss	Rate of Flow of Oxygen	Intrinsic Fluidity	Weight Loss
hr.	ml/min.		%	ml/min.		%
0	—	0.56	—	—	0.56	—
4	1.0	0.60	Negligible	54	0.63	1.5
8	1.0-1.2	0.67	"	53-54	0.68	3.5
12	1.0	0.78	"	54	0.83	4.3
16	1.2	1.09	"	53-54	1.05	4.7
20	1.0	1.37	1.0	53-54	1.26	7.6
24	1.0	1.95	1.3	53-54	1.52	7.7

[1]Humidified by bubbling it through water at 30°C.

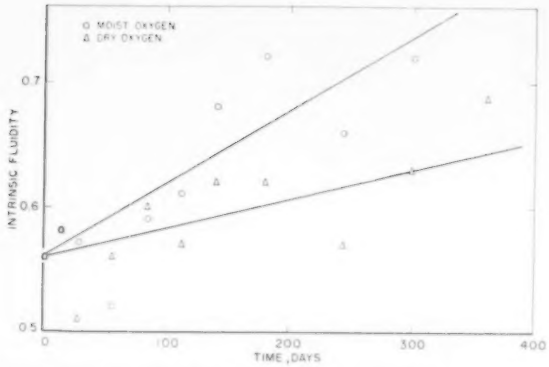

Figure 2. Degradation of film No. 4 (one mil) in moist and dry oxygen at 60°C.

mens, the rate of gas flow should not be critical if it is high enough to prevent decomposition products from accumulating and catalyzing the degradation. The diffusion rate of oxygen into the film, and the diffusion of degradation products out of the film, are usually not critical for cellulose acetate films less than about 9 mils thick (Ref. 11.) Specimens of film No. 4, which is oxidation-sensitive, were exposed in a special reaction vessel to two rates of flow of oxygen, about one ml per minute and about 54 ml per minute. The data are given in Table III; it is obvious that the rate of gas flow within these limits is not critical for intrinsic fluidity changes. The weight loss (plasticizer loss) was much greater with the high rate of gas flow. The weight loss of unplasticized films was negligible.

Data were obtained on the degradation of film No. 4 in moist and dry oxygen at 60°, 94°, 110°, 124°, 140°, and 177°, in moist and dry air at 140°, in moist and dry nitrogen at 110° and 140°, and in dry nitrogen at 177°C. Data on the degradation in nitrogen are given in Table IV. Intrinsic fluidity is plotted against time in moist and dry oxygen at 60°C in Fig. 2, and at 110°C in Fig. 3. These data are representative of the behavior of film No. 4.

Data were obtained on the degradation of the unplasticized film (cast from flake D in Table I) in moist and dry oxygen at 110°, 124°, 140°, and 176°, in moist and dry air at 140°, and in moist and dry nitrogen at 110° and 176°C. Data on the degradation in nitrogen are given in Table V. Intrinsic fluidity is plotted against time in moist and dry oxygen at 176°C in Fig. 4.

An initial rate of degradation is usually succeeded by a fairly abrupt increase in degradation rate. Straight lines are drawn through the experimental points and their slopes are calculated, in order to obtain measures of these rates. The first, or slow, part of the reaction is described as the "initial" reaction and the succeeding part of the curve is described as the "secondary" reaction. These are arbitrary terms and are not meant to indicate that the secondary reaction depends on the initial reaction.

The unplasticized and plasticized films show wide differences in degradation rates. However, in both cases, the degradation appears to be principally oxidative in nature. Film No. 4 did not show serious degradation after 39 days in nitrogen at 140°C (Table IV). In oxygen at this temperature, a similar degree of degradation had occurred in about 3 hours. The unplasticized film was seriously degraded in about 4 hours in oxygen at 176°C, but the degradation after 1 day in nitrogen (Table V) was not extensive. The pyrolytic

TABLE IV

Degradation of Cellulose Acetate Film No. 4 in Moist[1] and Dry Nitrogen at Various Temperatures

Time	Weight Loss	Intrinsic Fluidity
	%	
days	**Moist or dry nitrogen, 110°C**	
6	No significant change	
days	**Moist nitrogen, 140°C**	
0	—	0.51
1/3	1.1	.54
2/3	1.8	.50
1	3.0	.61
2	5.2	.59
3	11.5	.64
4	10.7	.67
5	11.6	.67
7	6.1	.65
11	15.3	.61
15	17.9	.62
20	19.8	.66
25	19.0	.80
39	19.1	.70
days	**Dry nitrogen, 140°C**	
0	—	0.51
1/3	1.1	.55
2/3	1.8	.50
1	2.8	.54
2	7.6	.63
3	11.6	.57
4	12.5	.54
5	13.6	.56
7	7.1	.58
11	14.9	.58
15	18.6	.53
20	18.8	.60
25	19.0	.69
39	19.5	.60
hours	**Dry nitrogen, 177°C**	
0	—	0.51
16	11.8	.73

[1]Nitrogen saturated with water vapor at 60°C.

TABLE V

Degradation of an Unplasticized Experimental Cellulose Acetate Film[1] in Moist[2] and Dry Nitrogen at Various Temperatures

Time	Weight Loss	Intrinsic Fluidity
	%	
days	**Moist or Dry Nitrogen, 110°C**	
28	No significant change	
days	**Moist Nitrogen, 176°C**	
0	—	0.49
1	Negligible	.65
4	"	.78
days	**Dry Nitrogen, 176°C**	
0	—	0.49
1	Negligible	.68
4	1.2	1.37

[1]Cast from flake D.
[2]Nitrogen saturated with water vapor at 60°C.

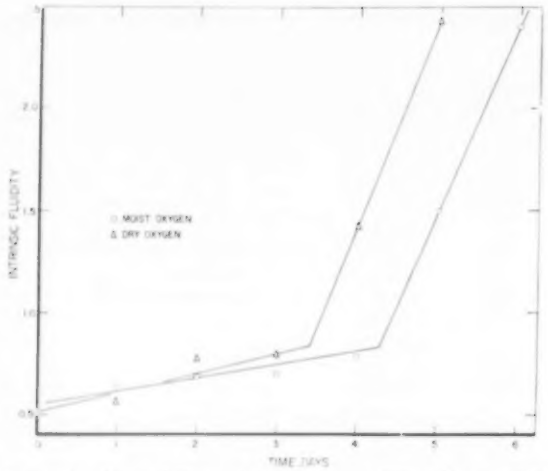

Figure 3. Degradation of film No. 4 (one mil) in moist and dry oxygen at 110°C.

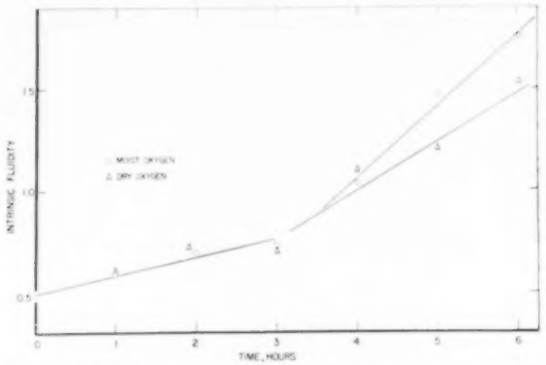

Figure 4. Degradation of an unplasticized experimental film (one mil), cast from flake D, in moist and dry oxygen at 176°C.

TABLE VI

Ratios of degradation rates[1] of cellulose acetate films in oxygen to degradation rates in air at 140°C

	Ratio of Degradation Rates in Oxygen and Air			
	Moist atmosphere		Dry atmosphere	
	Initial	Secondary	Initial	Secondary
Film No. 4	2.4	8.9	5.1	8.5
Unplasticized experimental film	3.6	10.6	4.9	6.7

[1]Degradation rates of the films degraded in air were taken from plots of intrinsic fluidity against time. Degradation rates of the films degraded in oxygen were taken from the Arrhenius plots in Figs. 5 and 6.

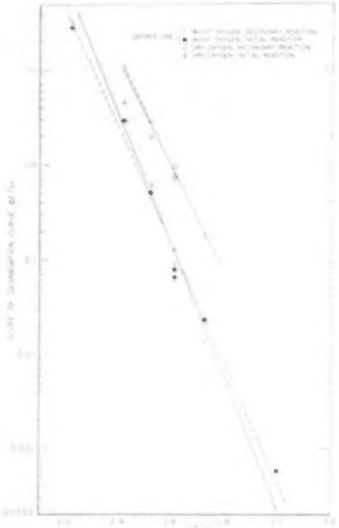

Figure 5. Arrhenius plots for film No. 4.

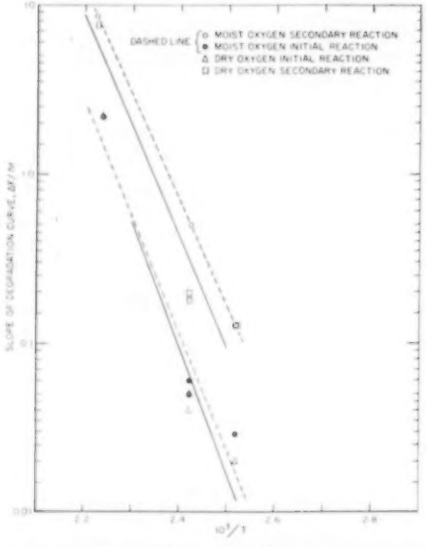

Figure 6. Arrhenius plots, unplasticized laboratory film.

degradation appears to be minor in comparison with the oxidative degradation for these two films.

The oxidation rate is a function of the partial pressure of oxygen in the atmosphere surrounding the film. The ratios of the slopes in oxygen to those in air at 140°C (Table VI) vary from 2.4 to 10.6 and the secondary reaction is much more sensitive to a higher oxygen concentration than is the initial reaction.

The slopes of the degradation curves in moist and dry oxygen at various temperatures are given in Table VII. These data have been plotted against 1/T on semi-log paper in Figs. 5 and 6. The activation energies calculated from the least-squares slopes of these plots are given in Table VIII. The activation energies for the secondary reactions for both films in both moist and dry oxygen are consistently less than for the initial reactions. Therefore, the initial reactions are more temperature-dependent than are the secondary reactions.

The initial rate of degradation of film No. 4 at 177°C is much higher than the secondary rate. Apparently, the rolled specimen fused, and the rate of diffusion became the rate-determining step rather than oxidation. Therefore, initial slopes only are included on the Arrhenius plot in Fig. 5.

TABLE VII

Slopes of Degradation Curves for Films Degraded in Moist and Dry Oxygen at Various Temperatures

Temp. C°	$10^3/T$	Slope of Degradation Curve: Moist Oxygen Initial ΔF[1]/day	Moist Oxygen Secondary ΔF/day	Dry Oxygen Initial ΔF/day	Dry Oxygen Secondary ΔF/day
		Film No. 4			
60	3.003	0.0006	—	0.00023	—
94	2.725	0.023	—	0.014	0.18
110	2.611	0.078	0.68	0.103	0.77[2]
110	2.611	0.065	0.91	0.09	0.98
124	2.519	0.50	2.9	0.60	2.0
140	2.421	2.95	9.4	4.6	Approx. 10
177	2.222	28.6	15.6	32.4	" zero
		Unplasticized Experimental Film			
124	2.519	0.029	0.128	0.02	0.13
140	2.421	0.06	—	0.05	0.18
140	2.421	0.05	0.50	0.04	0.20
176	2.227	2.22	8.57	2.22	7.6

[1] ΔF is change in intrinsic fluidity.
[2] Uncertain, but 0.77 is the minimum slope.

The vertical differences between the lines on the Arrhenius plots for the unplasticized and plasticized films represent between one and two cycles on semi-log paper. Therefore, the unplasticized film is over 10 times more stable than the plasticized film. As the slopes of the Arrhenius plots for the unplasticized film are numerically greater than for the corresponding plots for the plasticized film, these differences in stability would be accentuated if the plots were extrapolated to room temperature.

Data obtained in this study on the effect of moisture on the degradation of cellulose acetate are not sufficient to allow any definite conclusions to be drawn.

The data on the unplasticized film, with the exception of specimens aged at 110°C, were obtained with specimens washed for 10 minutes in distilled water at 60°C to remove the last traces of solvent. Unfortunately, this treatment also removed the stabilizing salts from the film and made the film more sensitive to oxidation. Some unwashed specimens were aged at 124°C for 50 days. In moist oxygen, the initial slope of the degradation curve was 0.003, and that for the secondary reaction was 0.015. In dry oxygen, the slope of the degradation curve was 0.01. Apparently, there was no initiation period. The unwashed film is almost ten times as stable as the washed film. In this particular film, stabilizing salts appear to contribute much more to oxidative stability than does removal of residual solvent.

Sulfuric acid is normally used as an acetylating catalyst in the manufacture of cellulose acetate, reacting with the cellulose to form an ester. Complete removal of this bound sulfate is quite impossible, and to reduce it below certain practical values, depending on the intended use of the product, is not economically feasible. Bound sulfate causes poor stability in cellulose acetate, but it may be neutralized by washing the acetate in water containing calcium or magnesium salts (Ref. 12.). Incorporation of an acid acceptor into the finished product is also helpful.

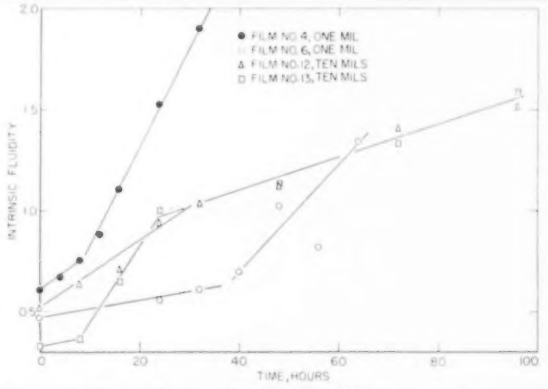

Figure 7. Degradation of commercial films in moist oxygen at 124°C.

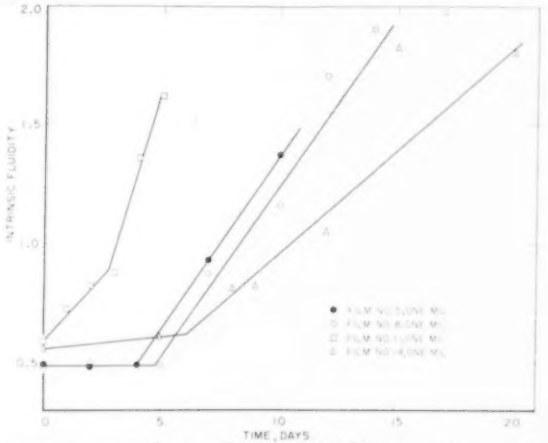

Figure 8. Degradation of commercial films in moist oxygen at 124°C.

TABLE VIII

Activation Energies from Arrhenius Plots for Films Degraded in Moist and Dry Oxygen

	Moist Oxygen		Dry Oxygen	
	Initial Reaction	Secondary Reaction	Initial Reaction	Secondary Reaction
	Kcal.	Kcal.	Kcal.	Kcal.
Film No. 4	28	26	31	25
Unplasticized experimental film	31	29	34	30

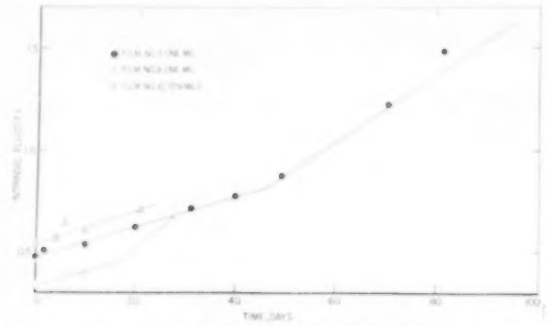

Figure 9. Degradation of commercial films in moist oxygen at 124°C.

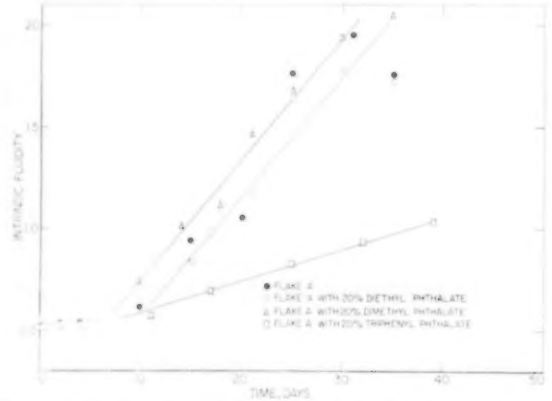

Figure 10. Degradation of experimental films (one mil) in moist oxygen at 124°C; flake A with various plasticizers.

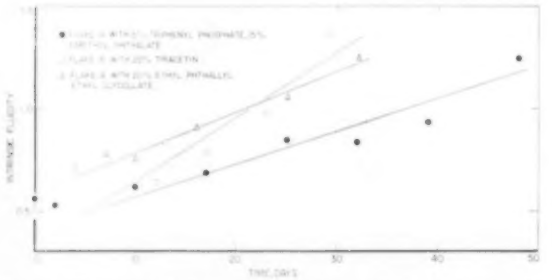

Figure 11. Degradation of experimental films (one mil) in moist oxygen at 124°C, flake A with various plasticizers.

Data on the production of acids during degradation were obtained, but were not sufficiently precise to warrant any conclusions except that carbon dioxide and organic acids were produced.

On the basis of the foregoing data, a single temperature was selected at which to study the degradation rate of other commercial and experimental films. The change in intrinsic fluidity of these films with time was determined at 124°C in flowing oxygen moistened with water vapor at 30°C. Less stable films are degraded in a day or two at this temperature, whereas more stable films may last two to three months. The selection of the concentration of water vapor was arbitrary, as water vapor did not appear to have any great influence on the rate of degradation.

Degradation of commercial films in oxygen at 124°C.—Data on the degradation of 11 commercial films in moist oxygen at 124° are plotted in Figs. 7, 8, and 9. Films No. 10 and 14 are extruded films, whereas the remainder are cast films. These films show very great differences in rate of degradation. Nos. 9 and 10 were not aged long enough for us to determine the shape of the aging curve. The remainder of the films, with the exception of Nos. 12 and 13, show the typical slow initial reaction or initiation period followed by a more rapid degradation. A rapid initial reaction followed by a slower reaction is exhibited by Nos. 12 and 13.

The degradation rates of several cellulose acetate flakes were studied in moist oxygen at 124°C. While some gave the typical degradation curve, others exhibited an extremely rapid secondary degradation reaction.

Degradation of experimental films in oxygen at 124°C.—The degradation rates of several films formulated from flake A are shown in Figs. 10, 11, and 12 as part of a study of the effect of typical plasticizers on stability. Each plasticized film contains 20% of plasticizer, based on total weight of film. These plots are typical in showing the complicated nature of the degradation of cellulose acetate formulations.

As shown in Figs. 10 and 11, plasticizers can greatly change the length of the initiation period as well as the rate of the secondary degradation. In agreement with published data (Ref. 3.), triphenyl phosphate acts as a stabilizer. Ethyl phthalyl ethyl glycolate acts as a stabilizer for the secondary reaction, but shows an initial rapid reaction rather than an initiation period.

Data are plotted in Fig. 12 showing the degradation rates, in moist oxygen at 124°C, of four films containing ether-ester plasticizers. It is obvious that esters containing an aliphatic ether linkage contribute greatly to the oxidative degradation of cellulose acetate films under these experimental conditions. The film containing methoxyethyl phthalate appears to be considerably more stable than the three other films, but it is still far less stable than the films for which data are plotted in Figs. 10 and 11.

Data on the degradation of films containing stabilizers are plotted in Figs. 13 and 14. The unplasticized film containing 2% of 2-hydroxy-4-methoxybenzophenone[3] (Fig. 13) is much more stable than the unplasticized film containing no stabilizer (Fig. 10). It is interesting to note that this stabilizer contains an ether linkage, but it is an aromatic-aliphatic ether. The four ether-ester plasticizers in the formulations in Fig. 12 contain only aliphatic ether linkages.

The degradation of two films containing dimethoxyethyl phthalate and a stabilizer is shown in Fig. 13. The relative effectiveness of the two stabilizers cannot be compared, as they were not present in equivalent concentrations.

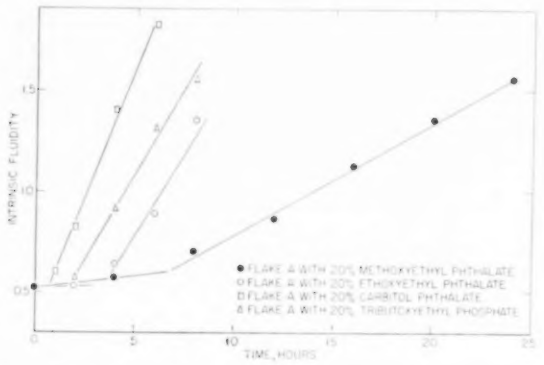
INTRINSIC FLUIDITY
TIME, HOURS
● FLAKE A WITH 20% METHOXYETHYL PHTHALATE
○ FLAKE A WITH 20% ETHOXYETHYL PHTHALATE
□ FLAKE A WITH 20% CARBITOL PHTHALATE
△ FLAKE A WITH 20% TRIBUTOXYETHYL PHOSPHATE

Figure 12. Degradation of experimental films (one mil) in moist oxygen at 124°C; flake A with various plasticizers.

Data on the degradation of film No. 4 recast without and with 1% of 2,6-di-*tert*-butyl-*p*-cresol are plotted in Fig. 14. There is little difference in the degradation rates of the original film and the film recast without a stabilizer. The film recast with 1% of stabilizer shows little degradation up to 80 hours, after which the slope of the degradation curve approximates that of the original film.

Data on the effect of acid and of acid acceptors on the degradation of experimental films are plotted in Fig. 15. Magnesium acetate acts as an acid acceptor and suppresses the degrading effect of sulfuric acid in the film.

The degradation of experimental films formulated especially for stability is plotted in Fig. 16. These two films[4] are duplicate formulations and appear to have about the same rates of degradation. The stability of these films is far greater than that of any of the other films for which data have been obtained.

Stress-Strain Characteristics of Degraded Films

In order to correlate intrinsic fluidity with useful physical properties of cellulose acetate film, several specimens of film No. 4 were aged in oxygen for 8, 16, and 24 hours, and in nitrogen for 40 hours. Intrinsic fluidity and tensile stress-strain data are given in Table IX, and typical stress-strain curves are plotted in Fig. 17. The elongation past the yield point (plastic flow) is degraded first, after which the tensile strength decreases. The film is very brittle and practically useless after 24 hours in oxygen.

It is interesting to note that the stress-strain data for the film heated for 40 hours in nitrogen at 124°C are very similar to those for the unaged film.

Effects of Hydrogen Chloride and Nitrogen Dioxide at Room Temperature

Data on the degradation of film No. 7 and experimental film No. II at room temperature, in air containing hydrogen chloride, are given in Table X. Apparently, the acid acceptor does not make the laboratory film any more resistant to hydrogen chloride than film No. 7, as the two films increase in intrinsic fluidity at about the same rate. An interesting result is that the specimens became insoluble in the viscosity solvent after a time, indicating that deacetylation is occurring much faster

[3]UV Absorber 9, American Cyanamid Co.
[4]Film No. II was supplied through the courtesy of Dr. W. D. Paist of the Celanese Corp. of America.

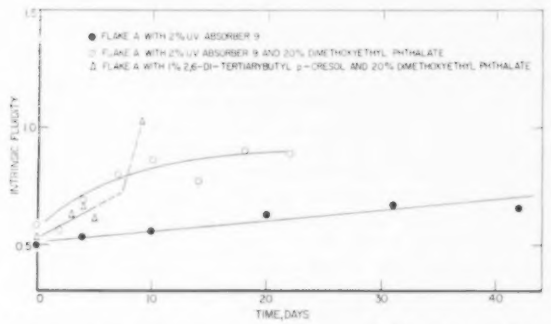
● FLAKE A WITH 2% UV ABSORBER 9
○ FLAKE A WITH 2% UV ABSORBER 9 AND 20% DIMETHOXYETHYL PHTHALATE
△ FLAKE A WITH 1% 2,6-DI-TERTIARYBUTYL p-CRESOL AND 20% DIMETHOXYETHYL PHTHALATE
INTRINSIC FLUIDITY
TIME, DAYS

Figure 13. Degradation of experimental films (one mil) in moist oxygen at 124°C; flake A with antioxidants and plasticizers.

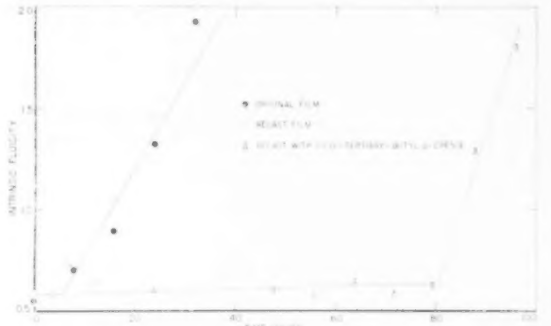

Figure 14. Degradation of a commercial film (one mil), recast with and without an antioxidant, in moist oxygen at 124°C.

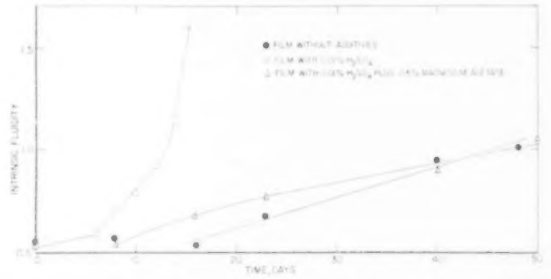

Figure 15. Degradation of experimental unplasticized films (one mil), formulated with acid and acid acceptor, in moist oxygen at 124°C.

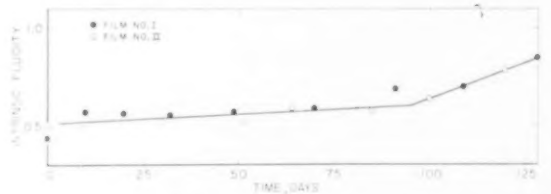

Figure 16. Degradation of archival formulations in moist oxygen at 124°C. The films (one mil) are duplicates with the following composition:

73% Cellulose acetate, flake E
5% Triphenyl phosphate
20% Dimethyl phthalate
0.5% Magnesium acetate tetrahydrate
1% Resorcinol monobenzoate
0.5% Di-tertiarybutyl *P*-cresol

than depolymerization under these particular experimental conditions.

Specimens of these two films were also exposed for varying lengths of time at room temperature to air at 47% relative humidity containing 0.2% of nitrogen dioxide. The data are given in Table XI. Although the intrinsic fluidity did not change appreciably, the films became insoluble in the viscosity solvent after a time, indicating the occurrence of deacetylation. The film strips, about 2 in. by 8 in., became tacky and gel-like, curled up into a ropy mass after 27 hours' exposure, and decreased about 10% in weight. Experimental film No. II became slightly yellow on exposure, but this appeared to be the only difference between the two films.

The composition of film No. 7 is not known; it may contain an acid acceptor or an antioxidant, or both. However, magnesium acetate in the concentration used in these experiments apparently does not prevent deacetylation either by hydrogen chloride or by nitrogen dioxide. Whether it would afford protection at lower concentrations of gas has not yet been determined.

As the hydrolytic depolymerization of cellulose acetate is more temperature-dependent than is its deacetylation, it is to be expected that deacetylation might cause the specimens to become insoluble in the viscosity solvent before much depolymerization has occurred.

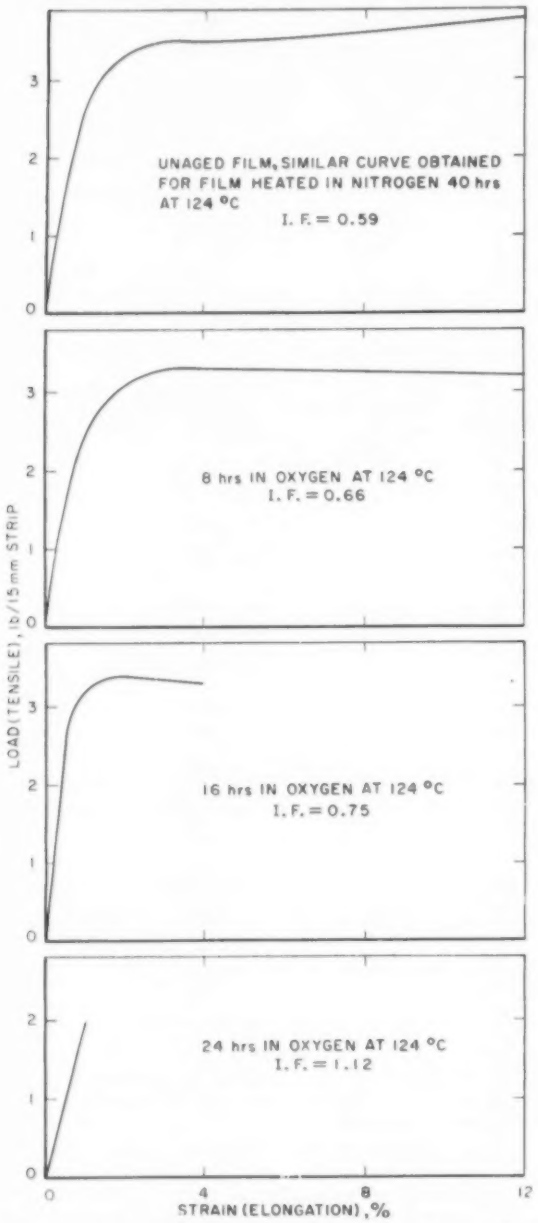
UNAGED FILM, SIMILAR CURVE OBTAINED FOR FILM HEATED IN NITROGEN 40 hrs AT 124 °C
I. F. = 0.59
8 hrs IN OXYGEN AT 124 °C
I. F. = 0.66
16 hrs IN OXYGEN AT 124 °C
I. F. = 0.75
24 hrs IN OXYGEN AT 124 °C
I. F. = 1.12
LOAD (TENSILE), lb/15 mm STRIP
STRAIN (ELONGATION), %
0
4
8
12

Figure 17. Stress-strain curves for film No. 4 (one mil) at various levels of intrinsic fluidity (I.F.).

Oxidation Effects

The attack on organic compounds by oxygen is believed to start usually with the generation of hydroperoxide as the initial product (Ref. 13). Apparently, such a reaction is very slow in unplasticized cellulose acetate that has the bound sulfate neutralized by an acid acceptor. The behavior of the unwashed experimental film mentioned earlier, and the data plotted in Fig. 15 on the degradation of a film containing an acid acceptor, show that oxidation is occurring relatively slowly.

The autocatalytic shape of the curve in Fig. 15 for the film containing 0.01% of H_2SO_4 is very interesting. If the depolymerization reaction were due principally to hydrolysis, a fairly straight line should result. It appears that sulfuric acid enhances the oxidation reaction, and, therefore, the formation of hydroperoxide. Evans and McBurney found that sulfuric acid increases the rate of oxygen uptake by cellulose acetate at 160°C (Ref. 1).

The data reported in this paper agree with the conclusion of DeCroes and Tamblyn (Ref. 3) that the plasticizer is often the chief contributor to the degradation of cellulose ester formulations. The action of specific plasticizers is often difficult to explain, as a plasticizer may affect the initial and secondary reactions differently. This is clearly demonstrated in Figs. 10 and 11. Differences may be ascribed to the molecular structure of the plasticizer, but the possibility of presence of catalytic impurities in the plasticizer cannot be overlooked.

The films containing ester plasticizers having an aliphatic ether linkage, shown in Fig. 11, probably owe their instability to the ease with which ethers form peroxides. A hydroperoxide is formed on the carbon atom adjacent to the ether oxygen atom (Ref. 13), and the hydroperoxide is then available to attack other ethers or cellulose acetate. Dimethyl ether is comparatively stable (Ref. 14) so oxidative attack on the plasticizers in Fig. 12 would be expected to occur at methylene groups adjacent to the ether oxygen atom. 2,2-Dimethoxyethyl phthalate has two such methylene groups per molecule, 2-2-diethoxyethyl phthalate has four, tributoxyethyl phosphate has six, and Carbitol[5] phthalate has eight. As each formulation contains the same weight of plasticizer, the relative proportions of CH_2 adjacent to an ether oxygen atom would be, in the same order as above 1, 1.82, 2.12, and 2.83. It would be an oversimplification to try to establish a quantitative relationship between (a) the relative proportions of CH_2, adjacent to the ether oxygen atom, present in the films and (b) the relative rates of degradation. However, it is obvious that the length of the initiation period and the rate of the secondary degradation are functions of the concentration of this particular organic grouping.

[5]Carbitol is a trade name for 2- (2-ethoxyethoxy) ethanol.

TABLE IX

Correlation of Intrinsic Fluidity with Physical Properties of Cellulose Acetate Film No. 4

Film No. 4 Aged as Shown below	Tensile at Break	Tensile Strength at Break	Yield Strength	Tensile Strength at Yield	Energy	Intrinsic Fluidity
	lb. 15 mm strip	%	lb. 15 mm strip	%	in.-lb.	
Not aged	3.9	11.2	3.9	3.5	1.61	0.59
Nitrogen 24hr. at 124°C	3.0	6.5	3.1	3.0	0.85	0.63
Nitrogen 40 hr. at 124°C	3.7	13.9	3.5	3.0	1.82	0.58
Oxygen 8 hr. at 124°C	3.2	11.9	3.3	3.2	1.46	0.66
Oxygen 16 hr. at 124°C	3.3	4.0	3.4	2.9	0.44	0.75
Oxygen 24 hr. at 124°C	1.9	1.0	—	—	0.05	1.12

The point of attack by the hydroperoxide from an ether-ester is not likely to be a hydroxyl group, as alcohols are fairly resistant to autoxidation. In fact, alcohols inhibit the catalyzed oxidation of long-chain paraffins (Ref. 15). DeCroes and Tamblyn (Ref. 3) have suggested that cellulose acetate is more readily attacked by peroxides than is cellulose, and the fact of the higher hydroxyl content of cellulose favors this suggestion. Because of the relative stability of alcohols, and the fact that an ether having a tertiary hydrogen atom adjacent to the ether oxygen atom is particularly susceptible to oxidation, the hydrogen atoms on carbon atoms 1 and 4 in cellulose and cellulose acetate would be expected to be particularly vulnerable. It is obvious, however, that the ether-ester plasticizers used in this study are much more susceptible to autoxidation than cellulose acetate. Apparently, oxygen has greater difficulty than has the peroxide formed by oxidation of the ether-ester in oxidizing cellulose acetate.

One factor in the facility with which easily oxidizable plasticizers contribute to degradation of a plastic is the greater mobility of the plasticizer with respect to the polymer. When a plasticizer hydroperoxide has been formed in the initiation step, it is free to diffuse and propagate the reactions with other plasticizer molecules and with the acetate. If the initiation step occurs on the polymer chain, the limited mobility of the latter greatly reduces the possibility of propagation before a termination reaction occurs.

Summary and Conclusions

1. The degradation of cellulose acetate films at elevated temperatures is essentially oxidative in nature.

2. The degradation curves, in general, are autocata-

TABLE X

Degradation of Cellulose Acetate Films at Room Temperature in Air[1] Containing Hydrogen Chloride

Time	Intrinsic Fluidity
hr.	
Film No. 7, 1.16% of Hydrogen Chloride	
0	0.47
24	0.64
48	0.76
75	1.19
Film No. 7, 0.12% of Hydrogen Chloride	
120	0.71
168	Specimens insoluble in solvent
Experimental Film No. II, 1.16% of Hydrogen Chloride	
0	0.48
24	0.65
48	0.76
75	Specimens insoluble in solvent
Experimental Film No. II, 0.12% of Hydrogen Chloride	
120	0.77
168	Specimens insoluble in solvent

[1]Relative humidity about 50%.

lytic in nature. A period of slow reaction, or sometimes no measurable reaction, is followed by a much faster reaction.

3. For the two films studied in detail, moisture did not have much effect on the rate of oxidation.

4. The oxidative degradation of film formulations is greatly influenced by the type of plasticizer.

5. Triphenyl phosphate appears to act as a stabilizer in cellulose acetate films. It does not increase the initiation period, but it greatly decreases the rate of the later stage of degradation.

6. Triacetin or ethyl phthalyl ethyl glycolate appeared to lower the rate of the secondary reaction. A film containing ethyl phthalyl ethyl glycolate gave an usual degradation curve, as no initiation period was shown.

7. Aliphatic ether-esters greatly accelerate the oxidative degradation of cellulose acetate films. However, a compound containing an aliphatic-aromatic ether linkage acted as an antioxidant.

8. Air containing 0.2% of nitrogen dioxide at room temperature does not affect the intrinsic fluidity of cellulose acetate films. However, upon continued exposure, the films became tacky and gel-like, curled into a ropy mass, and decreased about 10% in weight. They also became insoluble in the viscosity solvent.

9. Films exposed to air containing hydrogen chloride increased in intrinsic fluidity, and also became insoluble in the viscosity solvent. The latter effect indicated deacetylation.

10. The activation energy for the degradation in moist oxygen of an oxidation-sensitive, plasticized film was 26-28 kilocalories, and of an unplasticized film, 29-31 kilocalories. In dry oxygen, the values were slightly higher.

11. An increase in intrinsic fluidity affects the tensile stress-strain curve by first decreasing the elongation. When the elongation is decreased past the yield point, the ultimate tensile strength decreases and a typical stress-strain curve is no longer obtained.

12. Commercial films vary widely in their rates of degradation in oxygen at 124°C. Except for films for archival purposes and for outdoor weathering, this is probably of no consequence, as other properties would be of more importance for the intended use.

13. Several antioxidants and ultraviolet absorbers acted as stabilizers for cellulose acetate film aged in oxygen at 124°C. Magnesium acetate proved to be a suitable acid acceptor under these conditions.

14. For greatest stability, an archival film formulated from cellulose acetate should contain one or more stabilizers and an acid acceptor.

Acknowledgment

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This work was sponsored by the National Archives, Library of Congress, Army Map Service, and the Virginia State Library.

TABLE XI

Degradation of Cellulose Acetate Films at Room Temperature in Air[1] Containing 0.2% of Nitrogen Dioxide

Time	Intrinsic Fluidity
hr.	
Film No. 7	
0	0.47
2	0.48
6	0.47
18	0.47
27	Specimens insoluble in solvent
Experimental Film No. II[2]	
0	0.48
2	0.47
6	0.46
18	0.50
27	Specimens insoluble in solvent

[1]Relative humidity about 45%.
[2]Composition given on Fig. 16.

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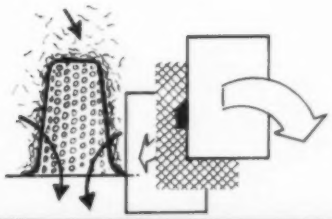


Edited by George Lubin
Grumman Aircraft Co.

REINFORCED PLASTICS

GROUND RADOMES

S. C. Nilo
M.I.T., Lincoln Laboratory

Large rigid ground radomes permit operation of radar systems under adverse climatic environments by sheltering the antenna from wind and ice which can impose severe structural and mechanical conditions. Ground radar systems have varying missions of aircraft and missile detection, tracking and interception. Radomes reduce the requirement for the high structural strength antenna construction needed to minimize the dynamic antenna deflection limits, and also reduce the excessive horsepower needed to drive the antennas under severe environmental conditions. Rigid radomes mechanically and economically permit the operation of precise, long-range radar systems.

The antenna performance properties of the various radar systems vary in electrical frequency, range, sensitivity and in mechanical size. Rigid radomes of several types and sizes have been developed with compatible radome-antenna electrical performance conditions. The conditions are those of minimum decrease in main beam, increase in side lobe level, boresight shift, and rate of boresight shift.

Table I entitled "Radome Survey Chart" presents the sizes, types and performance characteristics of rigid radomes currently in use, production or development. The radome types are categorized as uniform thin shell (reinforced plastics laminate, structural foam, and honeycomb sandwich) and space frame [metal-aluminum or steel, and dielectric (reinforced plastics)].

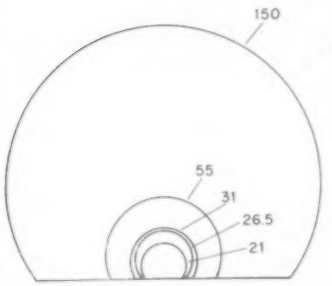
Fig. 1 graphically illustrates the extent of surface area and volume enclosed by radome sizes ranging up to 150 ft. in equatorial or spherical diameter which are tabulated in Table I. Lincoln Laboratory has designed or influenced the development of the bulk of the radome types listed therein.

The initial development was the LL 26A dielectric space frame design of 31 ft. equatorial diameter. It was fabricated by the wet layup method and was made up of 70 glass reinforced—Paraplex P-43, planar triangular panels. The triangles were of glass mat reinforcement in the membrane area and of cloth reinforcement in the integrally molded ¼-in. x 3-in. flanges. This structure was subjected to climatic and electrical tests and it was the first rigid radome of reinforced plastics for ground radar equipment design (Fig. 2).

Another radome of the same size and type was fabricated by the autoclave process (LL 26B). The basic structural elements are 70 hexagon and pentagon flanged panels. It is of mat construction throughout and the integrally molded flange is 3/16 in. x 3 in. The membrane thickness for the 26A and 26B designs are 3/16 in. and 0.045 in. respectively.

The CW 396A dielectric space frame of 55-ft. equatorial diameter which at present is the most widely used design was preceded by the LL 50A and 50B designs which consist of 361 total pieces (275 diamonds —86 hubs). The fundamental element in the 50A design is a flanged diamond shaped planar panel vacuum bag molded with glass mat reinforced Hetron 92 polyester resin. The integrally molded flanges are ¼ in. x 5 in. and the membrane thickness is 0.060 in. The minor axis of the diamond panel is a premolded post bonded reinforcing rib of CCA. The structure was statically load tested to 156 mph.

The 50B design differs in that triangular panels were vacuum bag molded and subsequently post bonded to form the reinforcing rib integrally at the diamond minor axis. This design which withstood a static load test equivalent to 220 mph without failure was of mat (0.060 in.) reinforcement at the membrane



SURFACE AREA (FT^2)	VOLUME (FT^3)
56,530	1,583,000
6,740	69,300
2,310	12,680
1,820	8,920
1,040	4,070

Figure 1. A comparison of surface area and volume enclosed by radomes up to 150 ft. in diameter.

Figure 2. The first rigid radome of reinforced plastics for ground radar equipment design.

TABLE I
Radome Survey Chart

SIZE			NOMEN-CLATURE	TYPE *		FREQ. BAND	ELECTRICAL PERFORMANCE				REMARKS
									BORESIGHT		
DIA.	BASE DIA.	HGT.		SHELL	SPACE FRAME		LOSS IN GAIN (db)	SIDE LOBE INCREASE @20-25 db LEVEL	SHIFT (mils)	RATE (mils/mil)	
18'	12½'	16½'	WSR-57	L		S	—	—	—	—	TESTS - NONE
26½'	20'	22'	CW-413	L		S	0.5	1 db	—	—	TESTS - FULL SCALE
26½'	20'	22'	MID-CANADA	L		S	0.5	1 db	—	—	TESTS - FULL SCALE
26½'	22'	21'	NRC POLYFOAM	F		S	<0.2	NEGLIGIBLE	—	—	TESTS - EXPERIMENTAL FULL SCALE MODEL
31'	26'	24'	LL-26B		L	L & S	0.5	1-2 db	—	—	TESTS - FULL SCALE
55'	50'	39'	CW-396A		L	L & S	0.5	NEGLIGIBLE - L BAND 2.5 db - S BAND	<1	—	TESTS - FULL SCALE
55'	50'	39'	CW-423	S		S	—	—	—	—	TESTS - FULL SCALE CONTINUING
55'	50'	40'	LL-50G	F		S & C	—	—	—	—	PROTOTYPE DESIGN
68'	56'	54'	CW-408		L	UHF	—	—	—	—	TESTS - NONE
68'	56'	53'	CW-491	F		UHF To C	—	—	—	—	PROTOTYPE DESIGN
110'	75'	95'	LAR		M	UHF	0.6	1 db	0.3	—	TESTS - SCALE MODEL
150'	123'	118'	CW-412		M	UHF	0.6	1 db	0.5	<0.01	TESTS - SCALE MODEL
155'	155'	77'	FAR		M	UHF	—	—	—	—	TESTS - SCALE MODEL CONTINUING

* F = FOAM L = LAMINATE M = METAL S = SANDWICH

TABLE II
Polyurethane Foam Dielectric Data
at 1000, 3000 and 8500 Mcps

DENSITY (lb / ft^3) (HOOKER 126 FOAM)	8500 Mcps		3000 Mcps		1000 Mcps	
	Tan δ	∈	Tan δ	∈	Tan δ	∈
2.5	0.00065	1.040	0.00053	1.040	0.00038	1.040
6.7	0.00162	1.100	0.00159	1.100	0.00159	1.105
13.6	0.0028	1.24 ±0.015	0.0029	1.24	0.0026	1.25

	10,000 Mcps		3000 Mcps		1000 Mcps	
	Tan δ	∈	Tan δ	∈	Tan δ	∈
POLYETHYLENE (ALATHON)	0.0004	2.25	0.0003	2.25	<0.0004	2.25
POLYTETRAFLUOROETHYLENE (TEFLON)	0.00037	2.08	0.00015	2.1	<0.0002	2.1
POLYSTYRENE (SHEET ROCK)	0.00043	2.54	0.00033	2.55	<0.0007	2.56
STYROFOAM 103.7	0.00015	1.03	0.0001	1.03	<0.0002	1.03

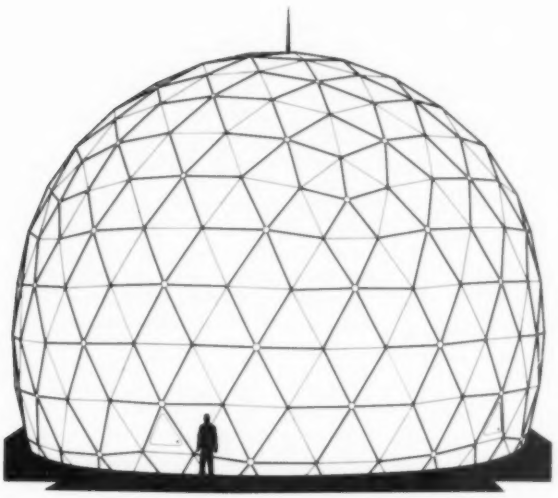


Figure 3. Icosahedron Geometry (CW-396A).

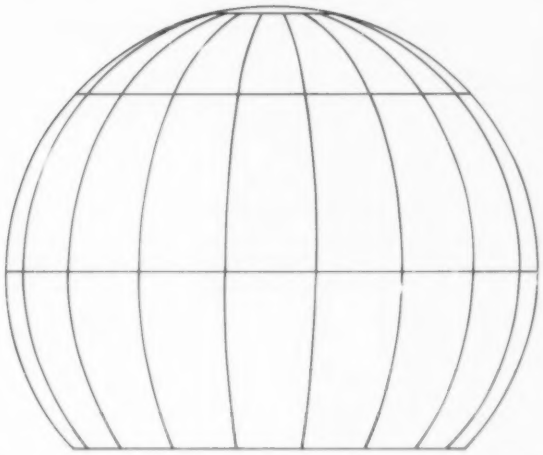


Figure 4. Segmented Orange Peel—20° Dihedral Geometry (CW-413).

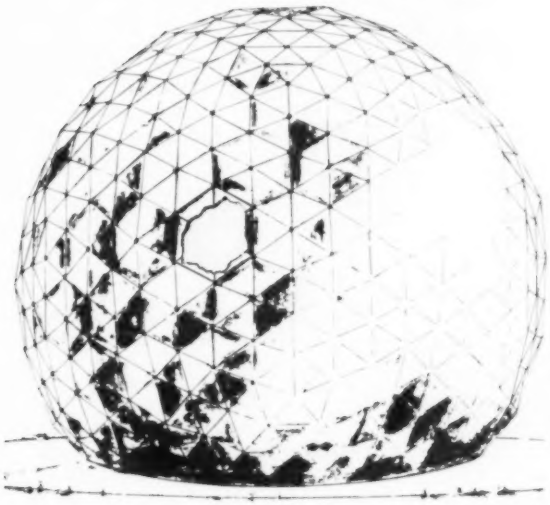


Figure 5. Icosidodecahedron Geometry.

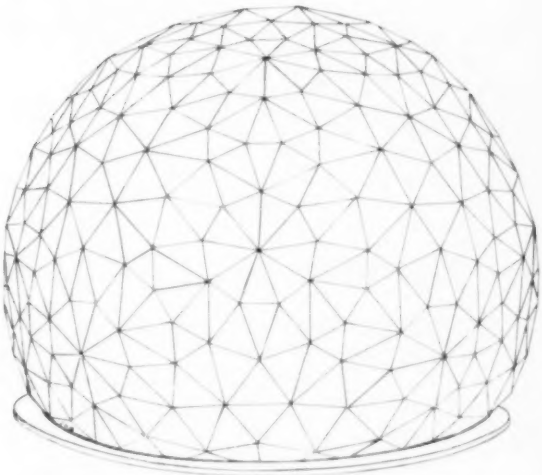


Figure 6. Trapezoidal Hexacontahedron Geometry metal Space Frame.

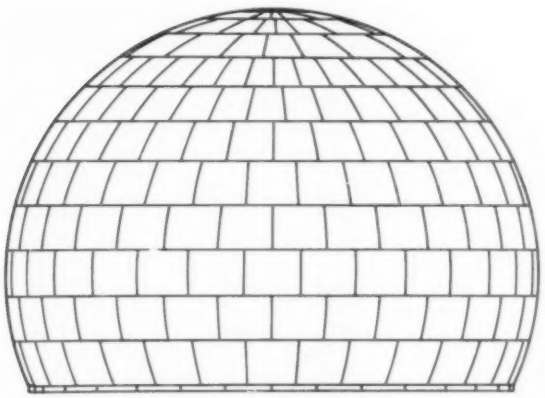


Figure 7. Segmented Orange Peel — 12° Dihedral Geometry (CW-413).

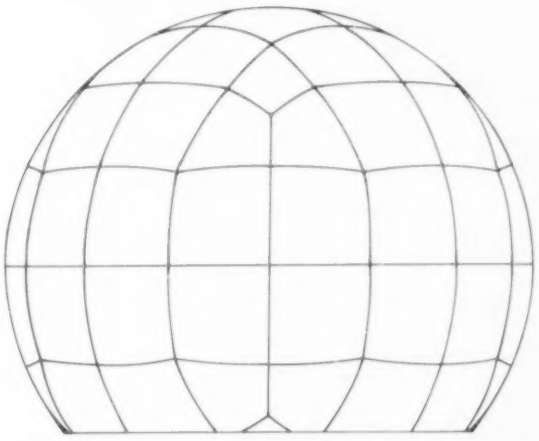


Figure 8. Small Rhombicuboctahedron Geometry — Foam.

TABLE III

Rigid Polyurethane Foam—Dielectric Data at 24,000 Mcps (effect of specimen orientation with foam rise direction).

DENSITY (lb / ft³) (Hooker 426 Foam)		24,000 Mcps						
		ϵ_1			ϵ_2			Tan δ
Measured	Nominal	PARALLEL TO FOAM RISE			PERPENDICULAR TO FOAM RISE			*
		FACE 1	FACE 2	AVG.	FACE 1	FACE 2	AVG.	
10.25	12.5				1.480	1.479	1.480	
10.29	12.5				1.479	1.480	1.480	.0024
10.38	12.5	1.479	1.479	1.479				
10.09	12.5	1.478	1.474	1.476				
24.81	25.8				1.439	1.443	1.441	.0048
26.38	25.8				1.457	—	1.457	
25.32	25.8	1.442	1.444	1.443				
24.45	25.8	1.399	1.428	1.414				
33.48	33.0				1.592	1.591	1.592	
32.69	33.0				1.578	1.575	1.577	
33.08	33.0	1.642	1.623	1.648				
34.34	33.0	1.603	1.646	1.640				.0063

* LOSS TANGENTS WITHIN EACH GROUP ARE WITHIN 5% OF VALUES SHOWN.

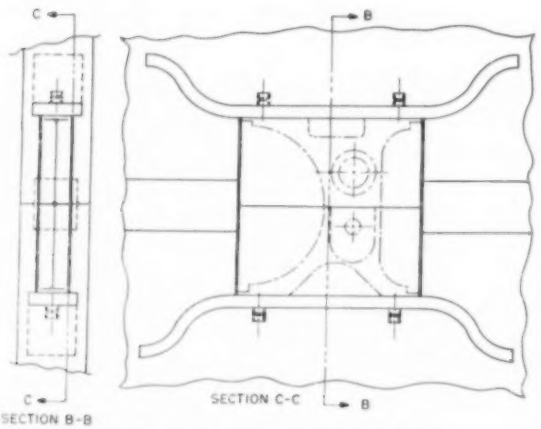


Figure 9. Alignment and Weather Key.

and of cloth reinforcement at the integrally molded flanges with Plaskon 941 polyester resin.

The CW 396 design reduced the hub size from 24 in. to 8 in. in the LL 50A design. It was the first rigid radome in production quantity and was installed at various Dew Line sites in the summer of 1956. The CW 396A, Fig. 3, replaced the mat construction with cloth construction and thereby reduced the flange depth down to 3 in. thereby permitting operational performance at both L and S band frequencies with negligible electrical effects upon the free space antenna pattern (see Table I). This type has been installed in the Far East and has successfully withstood average winds of 150 to 160 mph with occasional gusts in excess of 200 mph during 30 minute periods.

The CW-413 26½-ft. equatorial diameter shell design consists of 55 spherical panels (one spherical cap section) and 54 truncated gore or orange peel sections having a 20° dihedral angle, Fig. 4. The panels are ⅛-in. isosceles trapezoidal sections interconnected by butt joints at integrally molded approximately 1-in. deep panel edge flanges. One initial radome has been fabricated of autoclave molded unidirectional preimpregnated linearly aligned fibrous glass roving (Scotchply No. 1002) plied in the layup process to yield a crossply construction. Electrical tests at *S* band have been performed in addition to mechanical full scale tests. The design is for 150 mph winds.

The CW-412 metal space frame 150-ft. equatorial diameter radome design is for use with extremely large antennas where the mechanical considerations place limiting economic and operating factors on system performance.

Figure 10. Result of Tensile Pull-out Test. →

TABLE IV

Dielectric Data

DENSITY (lb/ft³)	POLYESTER POLYURETHANE RIGID FOAM	8500 Mcps		3000 Mcps		1000 Mcps	
		Tan δ	ϵ	Tan δ	ϵ	Tan δ	ϵ
2.5		0.00065	1.040	0.00053	1.040	0.00038	1.040
6.7		0.00162	1.100	0.00159	1.100	0.00159	1.105
13.6		0.0028	1.24 ±0.015	0.0029	1.24	0.0026	1.25
GLASS CLOTH POLYESTER LAMINATE (184-50 HETRON 92 VOLAN A)		.0170	4.48	.0147	4.50	0135	4.51
NEOPRENE COATED NYLON FABRIC (NEOPRENE - 2 PLY, 8 OZ/YD² NYLON)		8600 Mcps					
		.0386	3.98	058	407	069	4.09
		10,000 Mcps		3000 Mcps		1000 Mcps	
		Tan δ	ϵ	Tan δ	ϵ	Tan δ	ϵ
POLYETHYLENE (ALATHON)		0.0004	2.25	0.0003	2.25	<00004	2.25
POLYTETRAFLUOROETHYLENE (TEFLON)		0.00037	2.08	0.00015	2.1	<0.0002	2.1
POLYSTYRENE (SHEET STOCK)		0.00043	2.54	0.00033	2.55	<0.0007	2.56
STYROFOAM 103.7		0.00015	1.03	0.0001	1.03	<0.0002	1.03

The original geometry derived was the icosidodecahedron, Fig. 5, which is suitable for either but not both vertically or horizontally polarized antennas depending on the plane chosen for truncating the sphere. The random geometry finally evolved which has minimum orientation with the antenna polarization is the trapezoidal hexacontahedron, Fig. 6. This design consists of 820 fibrous glass mat—fire retardant polyester resin laminate triangles with integrally molded flanges. Mat thickness is 0.065 in. and 3/16 in. at edges. The total weight of panels equals 31,200 lbs. The 1200 structural members are of aluminum 6061-T6 extrusions of maximum 15-ft. length (13,941 ft. total length). The members are box section type beams 5½ in. x 3 in. x ½ in. The design incorporates 2400 (preassembled with beam at factory) aluminum 7079-T6 forgings, and 396 circular aluminum 7075-T6 alclad hubs of 13½ inch diameter. The random geometry is designed for 200 mph conditions and offers satisfactory electrical performance at UHF frequencies.

Increasingly severe electrical performance requirements, particularly of boresight shift and rate of boresight shift have required a construction which would result in continuous thin shell design of consistent and efficient dielectric properties throughout. The fabrication and electrical requirements of a homogeneous thin shell structure composed of structural material having low loss tangent and dielectric constand properties prohibit the general employment of solid laminate and sandwich materials, whereas the expandable plastics materials permit the construction of large structures with the ultimate elimination of panel joint discontinuity i.e., panels

TABLE V

Summary of Results

SPEC. NO.	MATERIALS		WELD STRESS AT FRACTURE (psi)	AVERAGE STRESS (psi)
	PANELS	WELD		
1a	H H	3M*	47.3	93.5
1b	H H	3M*	104	
2a	H H	3M*	121	
2b	H H	3M*	89	
3a	H H	3M*	95.5	
3b	H H	3M*	99.9	
4a	H H	3M*	98	
4b	P P	3M*	84**	
5a	H H	3M#	142	123.5
5b	N P	3M#	52**	
6a	H H	3M#	117**	
6b	P P	3M#	105	
7	H H	P**	114	115
8	P P	P**	85**	
9	H H	P**	116	
10	H H	P**	114	
11	P P	P**	61**	

SYMBOLS

H HOOKER 126P (HETROFOAM 11), 14 pcf NOMINAL.
P PITTSBURGH PLATE GLASS, SELECTROFOAM, 14 pcf NOMINAL.
N NOPCO CHEMICAL CO., A-213-SS, 13 pcf NOMINAL.
3M MINNESOTA MINING & MFG. CO., SCOTCHFOAM
* 4-6 pcf NOMINAL 9-10 ACTUAL
\# 14-19 pcf NOMINAL 12-13 ACTUAL
P ** 14 pcf NOMINAL 11-12.5 ACTUAL
** FRACTURE NOT AT WELD (NOT INCLUDED IN AVERAGES.)
3M*,# WELD MATERIAL AUTOMATICALLY DEPOSITED.
P** WELD MATERIAL BATCH DEPOSITED.

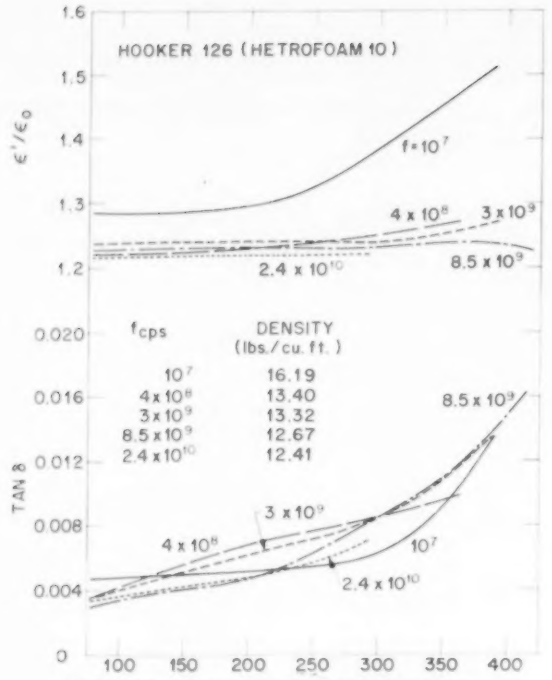


TABLE VI — Microwave Dielectric Properties.

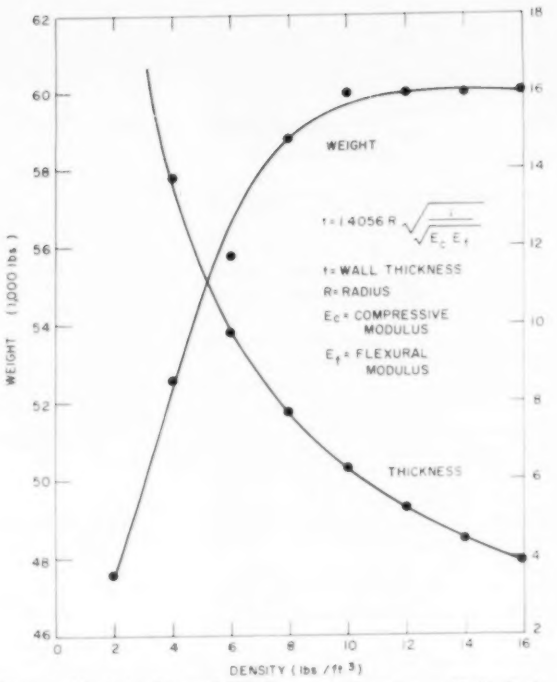


Figure 11. Weight and Thickness vs. Density — 68 ft. Radome (Hooker 126 Foam).

become permanently bonded to each other by sprayed on, poured or deposited prefoam polyester polyurethane resin of formulation such that the resultant density will match that of the factory precast polyurethane panel. Various polyurethane foam densities (from 2.5 to 33.0 lbs./ft.^{3}) were tested to determine the tan delta and dielectric constant properties at 1000, 3000, 8500 and 24000 mcps (Tables II and III). Table IV includes microwave dielectric properties on glass cloth-polyester laminate and neoprene coated nylon fabric. In addition dielectric characteristics for polyethylene, polystyrene, polytetrafluoroethylene and Styrofoam are included for comparison.

The requisite mechanical properties of a radome structural foam to be used *per se* as the load bearing member and not as the core constituent of a sandwich panel construction include: necessary modulus of elasticity and ultimate (or yield) strength in compression, flexure and tension; ageing resistance under conditions of temperature, relative humidity, weatherometer and salt spray accelerated tests, minimum water absorption; good microwave dielectric constant and tan delta; resistance to creep deformation under ambient and temperature loading fire retardancy; and impact and erosion resistance. The LL-50G design, Fig. 7, for a 55-ft. equatorial diameter radome of structural polyester polyurethane foam consists of staggered isosceles trapezoidal sections of segmented orange peel 12° dihedral geometry. The precast panels are mechanically interconnected by mechanical fasteners which are connected to embedded metal anchor plates, Fig. 9. A tensile pull-out test is illustrated in Fig. 10.

The CW-491 68-ft. equatorial di-

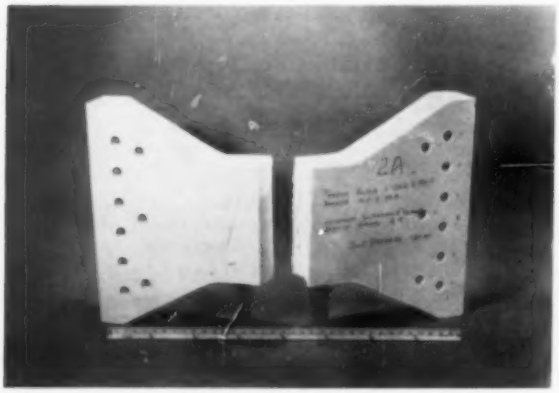


Figure 12. Joint Weldment Test — Specimen 2A.

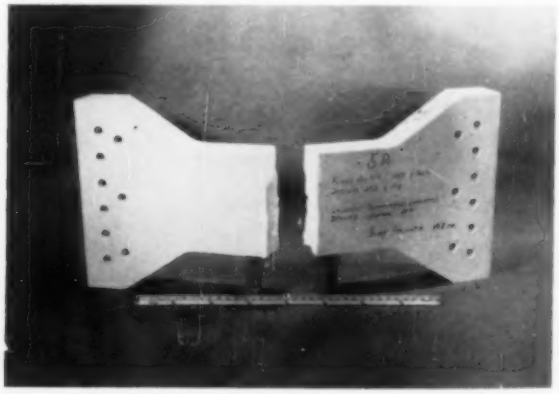


Figure 13. Joint Weldment Test — Specimen 5A.

ameter foam design geometry is similar to that evolved for the 26½-ft. design i.e., it is based on a circumscribed small rhombicuboctahedron, Fig. 8. There are a total of 276 panels of essentially equilateral spherical triangles and spherical quadrilaterals. There are a total of 9 different types of panels. The panel edges have machined semi-elliptical grooves which on temporary joining with mechanical straps form blind cavities into which foam is subsequently delivered for final radome erection by panel weldment with polyurethane foam. Therefore a uniform thin shell electrically broadband radome results by the foamed joint method. Fig. 11 illustrates weight and thickness versus density relationship for a 68-ft. polyurethane foam radome for critical buckling failure criteria. The values of modulus of elasticity in compression and in flexure are based on published Hooker Chemical Corp. data for Hooker 126A (Hetrofoam 10).

The panel interweldment results from the adhesive bond of cured foam interfaces between adjoining precast panels. Various automatic metering, mixing and dispensing equipment was evaluated for the foam panel weldment technique study. The equipment was evaluated on the basis of ability to deliver metered foam material formulation constituents within panel edge seam cavities under field site erection conditions. Necessary features are: accurate delivery, over a small delivery rate range, below 5 lbs./min. of prefoam; rugged construction for shipment and handling during erection; long term maintenance free, reliable operation; and cost.

The 3-M Brand Formulator Model A and Turbulator Gun (consisting of a metering unit modified to handle polyester polyurethane rigid prefoam systems) was chosen. The mixing head is integral with the spray gun which is capable of delivering both pour and spray material.

As part of the foam weldment technique study, climatic conditions of temperature, humidity, and wind velocity are simulated in an environmental chamber in order to determine the joint efficiency of various foam formulations and also to determine the optimum climatic conditions for panel weldment. Welded joints were made, using the 3-M Unit and both Scotchfoam I and Pittsburgh Plate Glass 6002-6003 weldments for panel weldment testing.

For this study a total of 34 foam tensile pull-out panels were cast by the batch process. They consisted of both one shot and/or prepolymer systems of Hooker 126, Pittsburgh Plate Glass 6002-6003 and Nopco Lockfoam B-614SS polyester polyurethane rigid foams of nominal 14 lbs./ft.^{3} density. The polyester resin, water, surfactant, catalyst and tolylene diisocyanate or isocyanate rich prepolymer formulation ingredients were mechanically dispersed by a Hobart Mixer.

Various panel edge configurations were considered, such as closed box channel, open V notch grooves, and closed elliptical channels.

The joint weldment tests are shown in Figures 12-16 and summarized in Table V. The low density Scotchfoam I welds yielded strengths between about 90 psi and 105 psi except for two values which were 47.3 psi and 121 psi. The two values obtained for the high density Scotchfoam I were 142 psi and 105 psi. The three values obtained for the Selectrofoam welds are 114, 114 and 116 psi. The low and high density Scotchfoam I welds were respectively in the density ranges of 9-10 and 12-13 lbs./ft.^{3}. The Selectrofoam welds were in the density range of 11-12.5 lbs./ft.^{3}

Table VI presents the microwave dielectric properties for a polyester polyurethane rigid foam of nominal 12 to 16 lbs./ft.^{3} at frequencies of 10 to 24000 mcps at elevated temperatures.

In conclusion increasingly larger antennas and the need for longer range and higher accuracy has resulted in the evolution of various rigid radome designs encompassing the relatively modest performance characteristics of aircraft early warning systems and the extreme precision needs of missile systems.

The Lincoln Laboratory radome design program has been presented generally and briefly. Current research and development efforts are in the field of large metal space frame radomes approximately 300 ft. diameter. Also, foam materials are being evaluated for system applications which require large radomes and have stringent electrical performance requirements.

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1. Climatic Tests of a Rigid Radome for Ground Systems by J. A. Vitale, J. M. Austin, S. L. Hensel, Jr., Sc.D.; Massachusetts Institute of Technology, Lincoln Laboratory; Paper presented at Ohio State University—WADC Radome Symposium, Vol. II, June 1955.
2. Materials Developments and Fabrication Processes In Radomes For USAF Ground Electronic

(*Continued on page* 172)

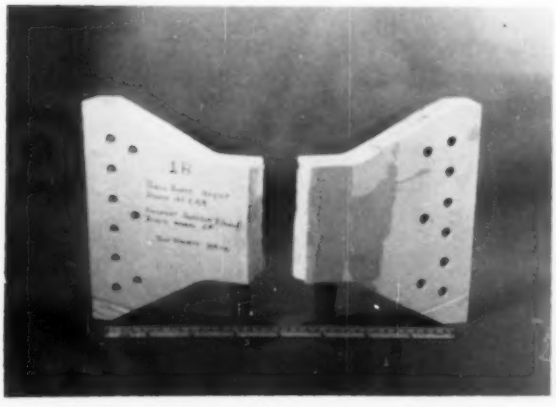

Figure 14. Joint Weldment Test—Specimen 1B.

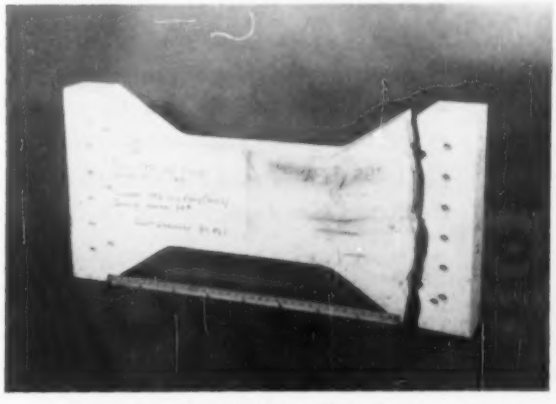

Figure 15. Joint Weldment Test—Specimen 8.

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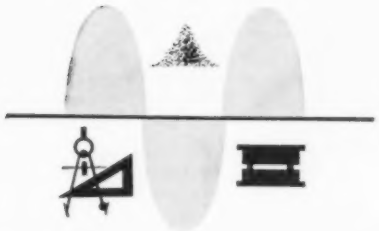

Edited by Louis Paggi, *Consultant*
E. I. du Pont de Nemours & Co., Inc.

MOLDING CYCLES

Answers to Your Molding Problems

Question

Will you please explain the meaning of the term "relative viscosity" and how is it determined?
(K.B.B.)

Answer

Relative viscosity may also be expressed as relative fluidity. The viscosity of sugar dissolved in water, for example, is greater than that of water alone when measured at the same temperature. When the term "relative viscosity" is used, we indicate that the viscosity of a given substance or solution of a substance is compared to or related to the viscosity of another substance.

When applied to plastics, it means the viscosity of a known percentage of a plastic dissolved in a solvent as compared to the viscosity of the pure solvent.

The apparatus used to measure relative viscosity consists of a tube having a restriction through which the fluid is allowed to flow by the pull of gravity, under controlled temperature conditions. Similar quantities of solvent as well as a solution of the plastic are allowed to flow through the restriction. The time required for the solution to pass the restriction divided by the time required for the solvent to pass the restriction is expressed as the relative viscosity.

For example:

The measured quantity of solvent will pass the restriction in 5 seconds. The same quantity of plastic solution requires 200 seconds to pass the restriction. The relative viscosity of the plastic solution is 40.

The Editor

Question

Are there any disadvantages in a long gate other than pressure loss? **(D.P.J.)**

Answer

The pressure loss in a long gate occurs only during the time of flow. Not after the cavity is filled. Other disadvantages are:

(1) Inability to "pack" the cavity because of earlier freezing of the material.

(2) A long gate will cause jetting of the material into the cavity more so than a long gate. The effect is similar to the relative difference in the scattering of a charge out of a long and a short barrel shotgun.

(3) Local entrapment of air and certain types of surface fold marks are more prevalent when long gates are used.

(4) The magnitude of stress occurring at the gate area is greater when long and narrow gates are used.

The Editor

Question

I notice increased usage of the word "mil" in reference to one-thousandth of an inch. Is a mil exactly equal to 1/1000 inch?
(Name withheld by request)

Answer

The word "mil" is from the Latin "mille" meaning one thousand. It refers to 1/1000 inch. The increased usage is because it is easier to say and to write.

The Editor

* * *

An old medical myth suggests you lower your head, thereby increasing the blood supply to that point and thus stimulate thinking. Well, we can't dispute the credence of this method, but we can suggest a more reliable means of eliminating doubts concerning molding problems.

Molding Cycles, your question box, offers expert information on all molding questions. Each month the Journal answers your inquiries with clear, concise explanations.

Years of experience enables specialists in this field to disseminate their views and findings in this column. Invaluable molding procedures are released to the readers of the Journal in response to their queries. Mr. Paggi has been engaged in plastics for thirty-two years, including six years in production, and thirteen years each in research and sales service. He invites you to send that "stickler" on to him for discussion in next month's column. We all know the challenges of every plastics engineer, but you can often find an easy solution to many of your molding difficulties. Unload your burdensome query on Louis Paggi's desk. Address him at Sales Service Laboratory, Polychemicals Dept., E. I. du Pont de Nemours and Co., Inc., Wilmington 98, Delaware.

Edited by R. D. Sackett
Hartig Extruders
Div., Midland-Ross Corp.

SPEAKING of EXTRUSION

Extrusion Workshop

Robert D. Sackett

Editor's Note—This is my final column as editor of Speaking of Extrusion. My new responsibilities do not allow sufficient time to continue this activity. I want to take this opportunity to thank all of the many people who have contributed to the feature during the past year and without whom it could not exist.

My appreciation also goes to Monsanto Chemical Co. (my former employer) for permitting me to expend the rather sizable amount of time required in maintaining this column since 1955.

The SPE has been fortunate in obtaining Bruce Maddock of Union Carbide Plastics Co. as the new editor of this column. He really needs no introduction to SPE Journal readers.

Since the Detroit SPE ANTEC in 1958, the PAG Extrusion Group has been working to set up an Extrusion Workshop. A Sub-committee composed of Robert Bostwick, Union Carbide Plastics; Dr. James Carley, *Modern Plastics* Magazine; Frank Nissel, Prodex Corp.; Jack Paton, Du Pont; Robert Sackett, Chairman, Hartig Extruders; Murray Underwood, Monsanto; and Earl Veazey, Dow, has been working with the various National Committees on setting up procedures and curriculum for this new SPE venture.

The first Workshop is scheduled to be held at Lowell Technological Institute at Lowell, Mass., on April 1 and 2, 1959. Registration is limited and priority will go to members of New England SPE local Sections. Priority will be assigned to only one member of a given company. At a later date other meetings will be scheduled at several regional locations.

The Workshop is sponsored by the Eastern New England Section. Their committee consists of Maynard Axelrod, chairman, Maynard Plastics; Donald Babbin, Simplex Wire; George Dougherty, Union Carbide Plastics; George Kovach (ENE President), Foster Grant Co.; Alberico Masciarelli, Rex Corp.; and Joseph McDonald, Guild Plastics. They are working on all of the final details for the meeting and members of New England Sections should have received complete details concerning this meeting by the time this is published. A $25 registration fee is anticipated with the proceeds being given to Lowell Tech by the Eastern New England Section to further their educational activities in the field of plastics technology.

Of all the various ways of processing plastics, extrusion has enjoyed the greatest development. This has been not only from a pure growth standpoint, but from the actual development of the theoretical understanding of the process. Many engineers responsible for the profitable operation of extrusion equipment have been unable to keep abreast of the latest technological developments due to the pressure of problems.

This series of informal classroom lectures and discussions will be of interest to engineers who see the wealth of theoretical information that is available today and want to apply it to their present processing problems.

The workshop will outline the foundation of modern extrusion theory in the areas of fluid flow and heat transfer. The main emphasis will be placed on the practical application of this theoretical matter to extrusion technology. Courses will be aimed at the extrusion engineer with training in mathematics and physics.

Included in the workshop will be 12 hours of regular classroom studies over a two-day period with a 2-hour panel discussion during the evening of the first day.

The Extrusion Workshop Committee has selected what it feels to be some of the best engineering talent available in the industry today as instructors. Each is well versed and has had a number of years of experience in the field they will cover. Outlined below are the details of the Workshop.

Moderator: Robert D. Sackett, Hartig Extruders

FIRST DAY

9:00-11:00 A.M.—Fundamentals of Plastic Flow and Heat Transfer
Instructor: Earl Veazey, Dow Chemical Co.

Topics covered will be a review of terminology, types of flow, methods of measuring flow, rheological data and interpretation and application of data in flow equations. Under heat transfer Mr. Veazey will review heat terminology, transmission methods in extrusion operation, and problems pertaining to heating and cooling of a plastic body.

11:00-12:00 A.M. — Introduction to Extrusion and Theory
Instructor — Dr. Ernest Bernhardt, Du Pont

This will include a very brief description of the extrusion process and utilization of basic concepts of flow in extrusion. The theoretical flow and energy equations necessary

PRODEX
EXTRUSION and COMPOUNDING SYSTEMS

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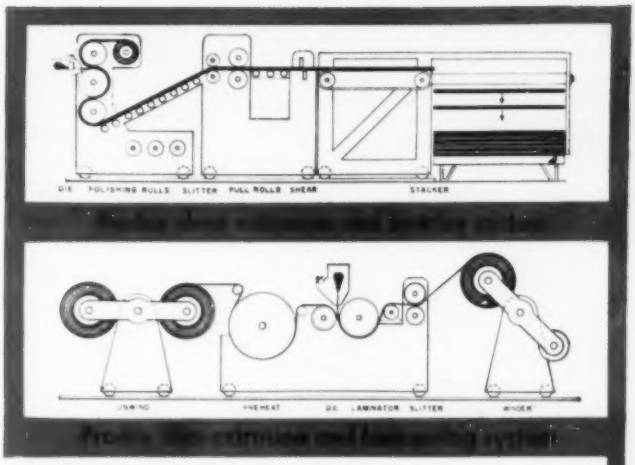

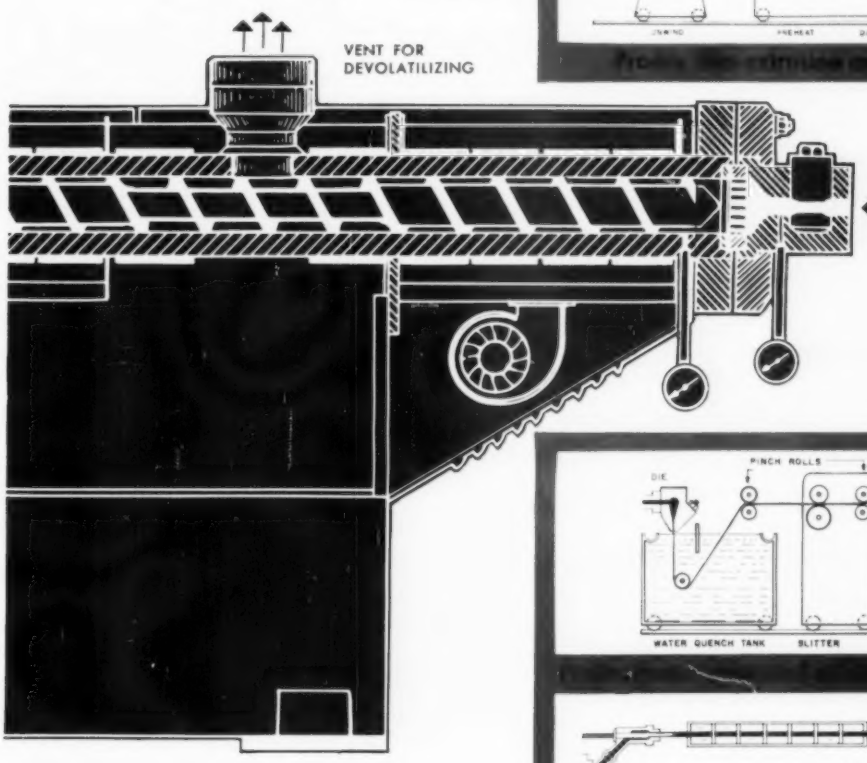

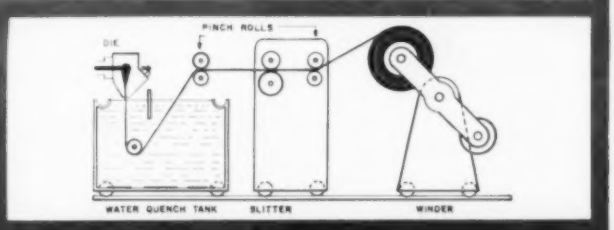

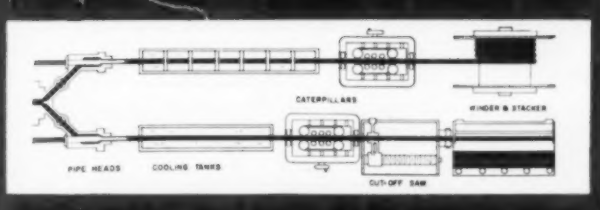

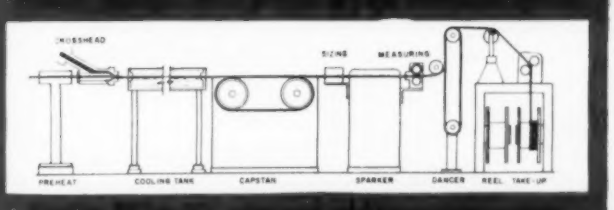

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for the development of specific extruder flow equation will be discussed. Throughout the lectures only the mechanisms of the derivations will be covered rather than actual derivations.

1:30-2:30 P.M.—Extrusion Theory
Instructor—Dr. James Carley, *Modern Plastics* Magazine

Equations pertaining to the isothermal, adiabatic and solids conveying section will be covered. Included will be a movie of actual flow in the extruder.

2:30-4:30 P.M.—Application of Design for Plasticating Extruders
Instructor — Dr. Ernest Bernhardt, Du Pont

This section will cover the design of the melt and solids section of the screw.

7:00-9:00 P.M.—Panel Discussion
All instructors present.

SECOND DAY

9:00-9:30 A.M.—A Practical Discussion of Flow in the Extruder
Instructor—Bruce Maddock, Union Carbide Plastics

Actual photographs of sections removed from the screw will be shown to give a clearer understanding of the transition zone of the extruder.

9:30-10:30 A.M.—Power Requirements
Instructor—Bruce Maddock, Union Carbide Plastics

The inter-relationship between heat energy and power requirements will be discussed with special emphasis on the practical application of such information.

10:30-11:00 A.M.—Scale Up
Instructor—Dr. James Carley, *Modern Plastics* Magazine

Problems pertaining to scaling up extruder design will be discussed.

11:00-12:00 A.M.—Die Design
Instructor—Dr. James Carley, *Modern Plastics* Magazine

Discussed will be the theoretical aspects of die design emphasizing the practical application of this theory.

1:30-3:00 P.M.—Extruder Instrumentation and Take-Offs
Instructor—Murray Underwood, Monsanto Chemical Co.

Desired extruder instrumentation and reasons why important will be discussed in detail. Also some of the engineering requirements of good take-off design will be covered.

3:00-4:30 P.M.—Machinery
Instructor—Frank Nissel, Prodex Corp.

This will be a discussion of important mechanical features of present day single screw extruders, including drives, bearings, thermal systems and maintenance.

★ ★ ★

Errata— Properties of Foams and Laminates Under Shock Loading

Editors Note—Corrections are made for pages 45 and 46 of the January issue.

The small change of dynamic, tensile and compressive moduli with density as density increases from 14 to 30 lb./ft.^{3} in contrast to the large change in the static values may be attributed to one or both of the following factors: (1) the mechanism of loading on the sample, (2) temperature effects.

Mechanism of Loading

In static tests in tension, for example, both polymeric chains and cell structure orient along the direction of pull, thus increasing the stiffness and tensile strength in the process. In dynamic tests, since the pulling action is complete in a few milliseconds, there is no time for such orientation to take place. This is indicated to some extent by the nature of the break. Samples broken in static tests possess a rough contour at the cross section. The cross section of the same material broken in dynamic tests is considerably smoother, almost conchoidal in appearance.

Temperature Effects

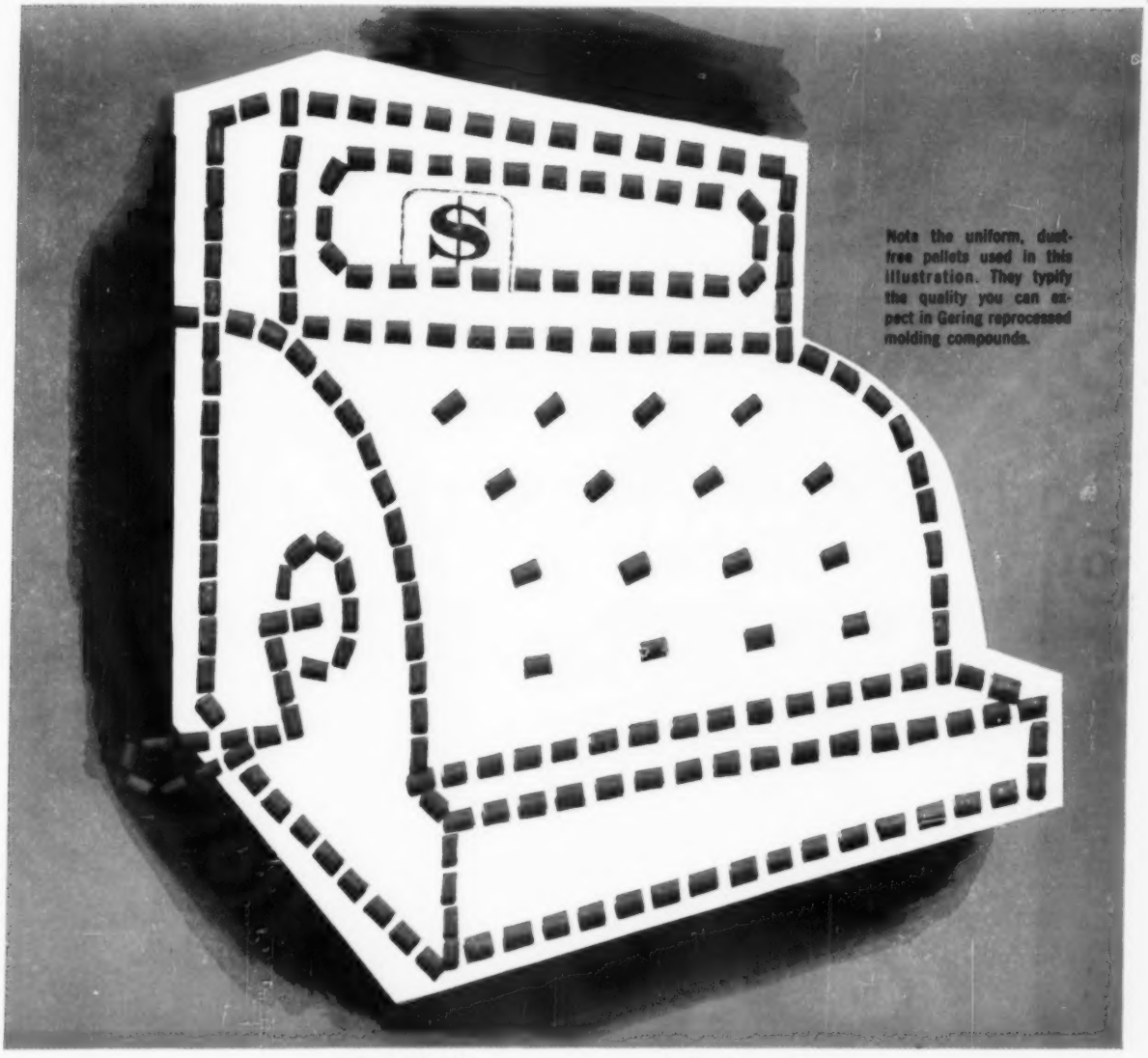
The time for fracture of the tensile specimen varied from 3 milliseconds for the 8 lb./ft.^{3} foam to 4 milliseconds for the 30 lb./ft.^{3} foam. During this rapid load application sufficient heat may have been generated to contribute to the low modulus of elasticity observed for the higher density foams. It is logical that this heat could be more readily dissipated into the air spaces of the low density foams so that this effect is not as noticeable in materials with densities below 14 lb./ft.^{3}.

Structural Laminates

Table 9 summarizes the test results obtained on structural laminates. Flexural and compressive tests were run on Paraplex 43, Hetron 92 and Epon 828 each made up into $\frac{1}{8}$-in. laminates with each of two glass cloths, 181 and 184 (Volan finish). As you can see, flexural modulus was 10-20% lower in the dynamic range than in the static range. Compressive modulus and compressive strength were also generally lower in the dynamic range than in the static range, but by an amount that was somewhat greater and less consistent from material to material. Flexural strength, however, was greater in the dynamic range than in the static range for all materials except Hetron 92 with 184 glass cloth. These values appear to correlate with the appearance of the broken specimen. Samples broken on the Plastechon showed more evidence of delamination than those broken on the Instron. Hetron 92 with 184 glass cloth, on the other hand, showed a completely different type of fracture on the Plastechon. One ply separated from the body of the specimen during the test, and this may have resulted in the lower strength value.

The large variation noted in comparative compressive properties is attributed to the small number of tests averaged. While five specimens were tested for each material, in some instances averages were based on less than five tests due to difficulties associated with testing technique. Refinements in technique are desirable to prevent misalignment of the compression cage and to prevent slippage of the extensometer.

★ ★ ★



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Edited by Thomas A. Bissell
SPE Executive Secretary

NATIONAL ACTION

1959 SPE NATIONAL OFFICERS

The 1959 SPE National Officers, left to right: Frank W. Reynolds, Secretary; Jules W. Lindau, III, Second Vice President; Frederick C. Sutro, Jr., President; George W. Martin, First Vice President; Haiman S. Nathan, Treasurer.

Election of 1959 SPE National Officers was the highlight of the National Council meeting held January 26th at Hotel Commodore in New York City. It is a sincere pleasure to present these men to the membership in this article.

Frederick C. Sutro, Jr., Kansas City Section, our new National President is well known throughout SPE as charter member of both the New York and Kansas City Sections. Fred is Products Manager—Polyethylene, Plastics Division, Spencer Chemical Company. Mr. Sutro received a B.S. degree in Industrial Engineering from Yale University in 1943. After service in the U.S. Air Force during World War II, Fred was associated with Bakelite Company and P.M. Industries, prior to joining Spencer Chemical Company in 1954. Fred is married and the father of two daughters. In SPE affairs, Sutro has served as National Membership Chairman and during 1958 as National Vice-President. I consider the Society extremely fortunate in having selected as President a man of Fred Sutro's capabilities and background.

New By-Laws adopted on second reading during the meeting, provide for the election of two National Vice-Presidents in keeping with the rapid growth of our Society. First National Vice-President during 1959 is George W. Martin of Western New England Section. George is President of Holyoke Plastics Co., Inc., Holyoke, Mass., and has been an SPE member since 1947. Since that time George has served SPE in many capacities including Chairman, Constitution and By-Laws Committee,

PAG Administrator and during 1958 as National Secretary. George is married and the father of four children.

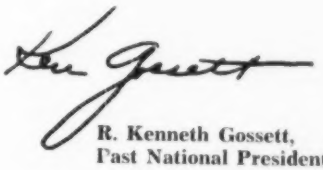
Jules W. Lindau, III, Southern Section is 1959 National Second Vice-President. Lindau was graduated from Rensselaer Polytechnical Institute in mechanical engineering in 1931, and is President, Southern Plastics Company in Columbia, South Carolina. Jules is well known in SPE for his work as Chairman and Administrator of the National Education Committee. He was National Secretary in 1955, Vice-President in 1956 and Treasurer during 1957. Jules is married and the father of four children.

Our new National Secretary is Frank W. Reynolds who was instrumental in forming our Binghamton, New York, Section in 1957. Reynolds is prominent as Manager, Plastics Research Laboratory, International Business Machines Corporation, Endicott, New York. Married and the father of five children, Reynolds performed outstanding service to SPE as 1958 National Membership Chairman.

H. S. Nathan, Buffalo Section 1959 National Treasurer, was graduated from Cornell University with a B.S. degree in Chemical Engineering. He has been President of Atlas Plastics, Inc. in Buffalo since 1946 and is active in several charitable and community organizations in that area. Nathan has served SPE ably in many capacities including the office of National Treasurer in 1955, National Vice-President in 1957 and Chairman of the 1958-1959 Finance Committee.

Council has elected a fine group of fellow officers to back Fred Sutro as National President. The team has been augmented by the addition of John Delmonte, Southern California Section, and Frank A. Martin, Akron Section as appointed members of the National Executive Committee.

The past year has seen solid progress in building the foundation for the Society's management in the period of rapid growth which lies immediately ahead. Development of revised Constitution and By-Laws, expansion of National office staff and relocation of National Office in Stamford, Connecticut have been accomplished. Future progress depends to a great extent on the activity of SPE members in the affairs of the Society. I hope that each of us, will accept our responsibilities of membership by participating actively in the Society's expanding technical program. Let's support our new National Officers in making 1959 the most outstanding year SPE has enjoyed!



R. Kenneth Gossett,
Past National President

THE PRESIDENT'S CUP

to Wayne I. Pribble

for Distinguished Service

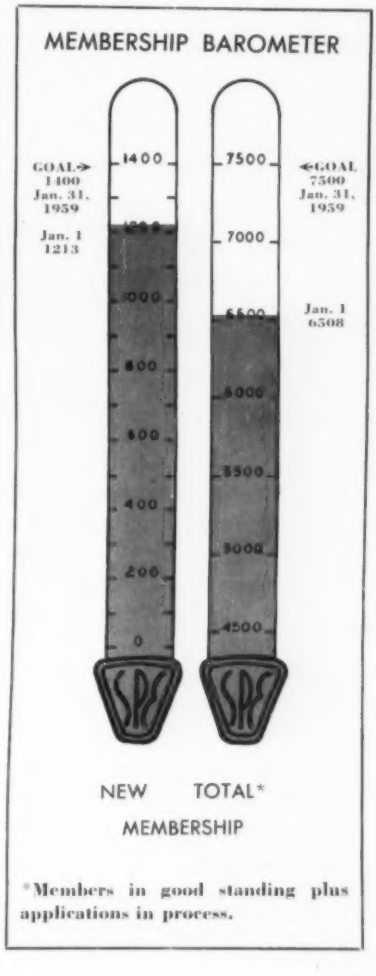
The second SPE President's Cup was awarded at the 15th ANTEC to Wayne I. Pribble, who, more than any SPE member, is responsible for our revised Constitution and By-Laws. The presentation was made at the banquet by R. Kenneth Gossett, 1958 National President.

The President's Cup is awarded by the Society to an SPE member (exclusive of National Executive Committee Members) who, in the opinion of the Executive Committee, has performed the outstanding service to the Society during the past year. The first President's Cup was awarded to Frank A. Martin, 1957 Chairman of SPE National Meetings Committee.

Mr. Pribble, president, Pribble Plastic Products, Inc., has served for many years as Councilman from Northern Indiana Section, and on the Constitution and By-Laws Committee. In 1957-1958 he was Chairman, and in 1958-1959 was Co-Chairman. He also functioned as SPE Parliamentarian much of this time.

Three years ago, Mr. Pribble began the task of reviewing past Council minutes to correlate previous proposals. At the 15th ANTEC the revised Constitution was accepted by unanimous vote at the Annual Meeting of Members for submission to the entire membership for letter ballot. The revised By-Laws were adopted by unanimous vote of Council following second reading at its meeting on January 26, 1959.

A report covering the important changes was presented by Arthur W. Logozzo, Co-Chairman, SPE Constitution and By-Laws Committee, in the National Action feature on page 59 of the November 1958, SPE Journal.



*Members in good standing plus applications in process.

Ground Radomes

(Continued from page 163)

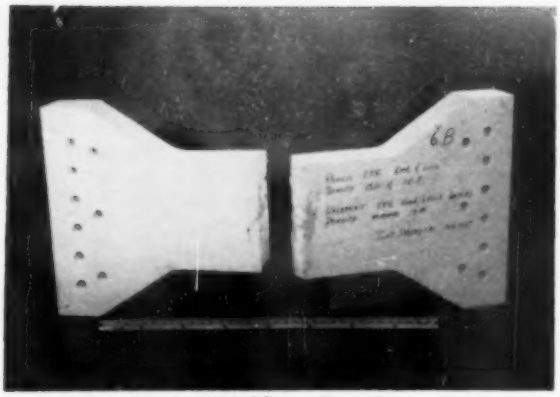


Figure 16. Joint Weldment Test—Specimen 6B.

Equipment by S. C. Nilo; Rome Air Development Center, ARDC, USAF: Technical Note RADC-TN-56-18, February 1956.

3. Rigid Radome Development by J. A. Vitale, D. G. Bagley, P. Davis, S. L. Hensel, P. G. Knowles, E. B. Murphy. Massachusetts Institute of Technology, Lincoln Laboratory; Paper presented at Ohio State University—WADC Radome Symposium, Vol. II 1956.
4. A 150-Foot Metal Space-Frame Radome, by A. Cohen, P. Davis, S. C. Nilo and J. F. Orabona; Massachusetts Institute of Technology, Lincoln Laboratory; Paper presented at Ohio State University Symposium; Proceedings of the OSU-WADC Radome Symposium, June 1957; WADC Technical Report 57-314, Vol. I, ASTIA Document No. A. D. 13-0930.
5. Structural Foam Radomes, by A. Cohen, P. Davis, S. C. Nilo and J. F. Orabona; Massachusetts Institute of Technology, Lincoln Laboratory; Paper presented at the OSU-WADC Radome Symposium; June 1958.
6. Survey of Radome Types and Their Electrical Performance Characteristics by M. M. Hannoosh, S. C. Nilo and A. Cohen; Massachusetts Institute of Technology, Lincoln Laboratory; Paper presented at the M. I. T., Lincoln Laboratory Symposium on Rigid Radomes, September 1958; Proceedings of the Symposium on Rigid Radomes.

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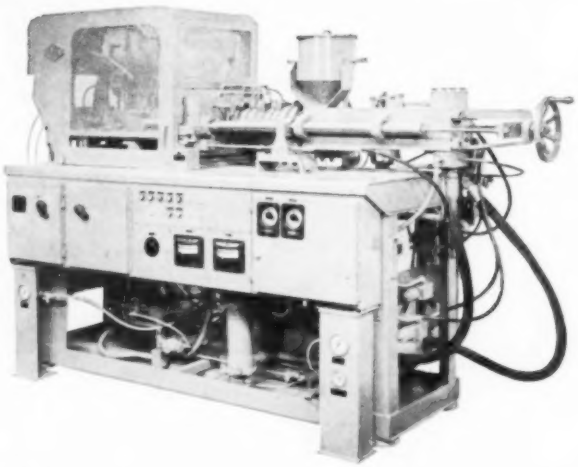
*dependent on material and mold construction



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TECHNICAL MEETINGS CALENDAR

16TH ANTEC

ANNUAL TECHNICAL CONFERENCE—January 12-15, 1960, The Conrad Hilton Hotel, Chicago, Ill. Sponsored by the Chicago Section. For more information, contact General Chairman Franklin L. Fine, Rohm & Haas Co., 5750 W. Jarvis Ave., Chicago 31, Ill.

WORKSHOP

EXTRUSION—April 1 and 2—Lowell Technological Institute, Lowell, Mass. Sponsored by the Eastern New England Section in cooperation with the Extrusion PAG. For more information, including complete program, see pages 166, 167 of this issue. For further information contact Robert D. Sackett, 15 Western View Circle, East Longmeadow, Mass.

RETECS

A DESIGNER'S LOOK AT REINFORCED PLASTICS FROM THE PLEASURE BOAT, AIRCRAFT AND MISSILES INDUSTRIES VIEWPOINT—April 28, 1959, Adolphus Hotel, Dallas, Texas. Sponsored by the North Texas Section. For information write to Chairman William McConnell, Air Accessories, Inc., 1400 Henderson St., Ft. Worth, Texas.

PLASTICS IN THE METAL INDUSTRY—May 7, 1959, Penn-Sheraton Hotel, Pittsburgh, Pa. Sponsored by the Pittsburgh Section. For information write to Chairman John Parks, Hydraulic Press Mfg. Co., 512 Empire Bldg., Pittsburgh 22, Pa.

PLASTICS IN ELECTRICAL INSULATION—May 22, 1959, Fort Wayne, Ind. Sponsored by the Northern Indiana Section in cooperation with the Plastics in Electrical Insulation PAG. Program includes papers on encapsulation, printed circuitry and fluidized bed coatings. For information write to Chairman Walter A. Gammel, Sr., RBM Controls Div., Essex Wire Corp., Logansport, Ind.

PLASTICS IN THE AUTOMOTIVE INDUSTRY—June 19, 1959. Sponsored by the Detroit Section in cooperation with the Plastics in the Automotive Industry PAG. For information write to Chairman John Donalds, The Dow Chemical Co., 450 Fisher Bldg., Detroit 2, Mich.

VINYL PLASTICS—October 7, 1959, Cleveland, Ohio. Sponsored by the Cleveland Section. For information write to William Messina, 414 Shawnee Place, Huron, Ohio.

PLASTICS FINISHING—October 16, 1959, The Niagara Hotel, Niagara Falls, N. Y. Sponsored by the Buffalo Section in cooperation with the Plastics Finishing PAG. For information write to Chairman Gordon K. Storin, 3 Forest Rd., Lewiston Heights, Lewiston, N. Y.

PLASTICS IN THE SHOE INDUSTRY—November, 1959, St. Louis, Mo. Sponsored by the St. Louis Section. For information write to Robert S. McDorman, Plastics Molding Co., 4211 N. Broadway, St. Louis, Mo.

PLASTICS IN PACKAGING—November 19, 1959, San Francisco, Calif. Sponsored by the Golden Gate Section. For information write to Chairman Bill Dodges, Hodges Chemical Corp., 1801 Spring St., P.O. 190, Redwood City, Calif.

STABILITY OF PLASTICS—December 1959, Washington, D. C. Sponsored by the Baltimore-Washington Section. For information write to George Flanagan, 1112 19th St., N.W., Washington 6, D. C.

SECTION MEETINGS

PITTSBURGH—February 19, 1959, Sherwyn Hotel, Pittsburgh, Pa. W. C. Wall and Howard H. Irvin will speak on "Mechanical Applications of Plastics."

CENTRAL INDIANA—February 24, 1959, Warren Hotel, Indianapolis, Indiana. A panel will discuss "Epoxies."

NORTHWESTERN PENNSYLVANIA—February 26, 1959, Eagles Club, Erie, Pa. A movie and talk will be presented on labor-management conflicts in a plastics plant.

WESTERN NEW ENGLAND—March 4, 1959, Bradley Field, Windsor Locks, Conn. A panel will discuss "The Needs of Our Customers in New England."

CHICAGO—March 9, 1959, Western Society of Engineers Building, Chicago, Ill. Topic of a talk to be given by Dr. James Carley will be "Relationship of Extrusion to Injection Molding."

BALTIMORE-WASHINGTON—March 10, 1959, Rolling Inn, Baltimore, Md. L. Stouffer, will give a talk on "Plastics in Packaging."

PIONEER VALLEY—March 12, 1959. Wachusett Country Club, West Boylan, Mass. William Olson will direct a panel discussion on material coloring.

CLEVELAND—March 16, 1959, Cleveland Engineering Society, Cleveland, Ohio. A field trip to Molded Fiberglass Co. in Ashtabula, Ohio, is planned for this meeting.

NEW YORK—March 18, 1959, Governor Clinton Hotel, New York City. A discussion on "Pigments for Vinyl Compounds" will be given by R. H. Zabel and L. R. Sherman.

SECTION NEWS

Western New England

Polystyrene Night

C. Judd Hold, Jr.

"Polystyrene" was the theme of the January 7th dinner meeting held at the Bradley Field Terrace Room in Windsor Locks, Conn.

Raymond A. Mazur, American Cyanamid, and Past President of this Section, was Technical Chairman.

Edward W. Veazey and Paul C. Woodland, both of Dow Chemical Co., jointly discussed "Polystyrene in Lighting."

Arthur W. Logazzo of Nutmeg Chrome Corp., also a Past President of the Section, spoke on "Mold Polishing," and showed an 18-minute film on the subject.

Announcement was made of Mr. Mazur's recent election as National Councilman.

Tulsa-Bartlesville

Organization Meeting

Ron Marsh

A group of 75 plastics engineers from Tulsa and Bartlesville met December 2 in Bartlesville to organize a new Section of SPE. Officers of the Steering Committee are J. N. Scott, Chairman; Roger McGlamery, Vice Chairman; Ron Marsh, Secretary; and Bill Barrett, Treasurer. Bob Martinovich was in charge of arrangements for the first meeting.

Speakers during the panel discussion were Ross Dean, Chairman of the SPE New Section Development Committee, who reviewed plans for forming a local Section; R. K. Gossett, 1958 SPE President, who discussed the objectives of the Society, and Don Eells, sales manager of Du Pont, who discussed the growth of the plastics industry.

Rochester

Flammability Tests

Peter T. Schurman

SPE National Treasurer was a guest at the November meeting. He discussed the *SPE Journal*, the rapid growth in membership, and the services which are performed by the National Office.

Technical speaker for the evening was Leroy Chellis of the IBM Plastics Laboratory who discussed the flammability of plastics. He pointed out that this was an area much neglected by material suppliers and fabricators. He discussed the different criteria of flammability and the confusion of terms which has arisen regarding this subject. Mr. Chellis also reviewed several of the tests available for measuring flammability, and then explained the IBM test which utilizes a high-frequency electrical arc.

TULSA-BARTLESVILLE—Officers and speakers at the organization meeting of the new Tulsa-Bartlesville Section of SPE are, left to right: J.N. Scott, Chairman; R.K. Gossett, 1958 SPE National President; Bill Barrett, Treasurer; Ross Dean, Chairman, SPE New Section Development Committee; Bob Martinovich, Arrangements Chairman; Roger McGlamery, Vice Chairman; Ron Marsh, Secretary; and Don Eells, guest speaker.

Connecticut

Polypropylene Properties

K. G. Clarke

An instructive and interesting discussion was given by Joseph J. Coughlan, technical sales representative from Hercules Powder Co., at the January meeting held at the Hotel Barnum in Bridgeport.

Slides and samples were used to illustrate the numerous comparisons between Hercules' new polypropylene resin Pro-fax as against the physical and mechanical properties of nylon which are now so well established.

Case histories in housewares, automotive, industrial and laboratory equipment further emphasized the broad capabilities of this material.

Early propylene polymers were soft and tacky because the atoms of the long chain molecules were arranged at random. New catalysts have made possible the orderly (isotactic) arrangement of the atoms in the polymer molecule thus producing the remarkable combination of high rigidity, low density, high tensile strength and melting point available in Pro-fax.

Early problems concerning oxidation, low temperature brittleness, light stability and sensitivity to certain metals of polypropylene are being overcome by unique compositions designed solely to eliminate these problems.

This new hydrocarbon polymer is promised a bright future in the world of thermoplastics.

New York

Radomes

Charles C. Orr

Airborne, semimonocoque and ground type radomes were discussed at the November meeting of the New York Section's REPPAG which met at Fairchild Engine Div., Deer Park, L.I. John Meirs, Grumman Aircraft Engineering Corp., moderated the program. Nearly 75 members attended.

Following dinner, J. Fitzgerald, Brunswick Balke Collender Co., spoke on airborne radomes. He traced their development from the rather crude original models to the highly sophisticated filament wound types that his company currently is making for aircraft and missile use.

The concept of semimonocoque radomes was explained by Richard Mark, Balsa Ecuador Lumber Corp., whose company is engaged in the development of this type structure. It partakes of both space-frame and stressed-skin principles, but does not fall completely into either category. The panels are to be made of glass mat reinforced polyester with a balsa wood core.

Ground radomes were covered by S. C. Nilo, Lincoln Laboratory, who reviewed the several structures currently in use with respect to their panel geometry and materials of construction. Ground radomes range in size from 18′ to 155′ in equatorial diameter. Since the larger units are made of composite, jointed panels, considerable energy losses are experienced through scattering, reflection and refraction. Among the panel geometries described were: segmented orange peel: segmented orange peel staggered from tier to tier; and triangular forms derived from icosahedron, icosidodecahedron and trapezoidal hexacontahedron shapes.

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Southern California RETEC Speakers

Among the speakers at the Regional Technical Conference on Plastics Trends in Building and Construction, held in Los Angeles November 13, were left to right: E. Balogh, Thomas A. Bissell (SPE Executive Secretary), Frank X. Ambrose, Vivian Rapp, D.R. Gray, L.J. Breidenbach, Paul Hunter, J.H. Layman, T.R. Von Toerne, Arthur N. Heath, Edwin A. Edberg, R. Kenneth Gossett (SPE National President, 1958), and Walter H. Kadlec.

Newark

Elect New Officers

David L. Sahud

The January meeting was held at the Military Park Hotel. Newly elected President Allen Serle introduced the new Officers, Directors and Committee Chairman to the dinner gathering and after-dinner arrivals.

Listed are the new Section leaders, who can be contacted at Newark Section office, 60 Park Pl., Newark 2, New Jersey.

OFFICERS: *President* — Allen Serle; *Vice-President* — Albert Spaak; *Secretary-Treasurer* — William B. Bradbury; *Director-at-Large*—Ernest J. Csaszar; *National Director*—Donald W. Biklen.

DIRECTORS: Norman H. Bragar, D.V. Blatter, Harrison N. Van Duyne, Frank Lombard, Victor Q. Merrill, James P. Fogarty, and Robert Bostwick.

COMMITTEE CHAIRMEN: *Executive Advisory*—John P. Lombardi; *Program*—Seymour S. Bodner; *House*—Oscar Pladek; *Membership*—Victor Q. Merrill; *Credentials*—Robert Bostwick; *Education*—Jerome S. Schual Jr.; *Library*—Ben Walker; *"What's New" Editor*—Robert B. Carter; *Job Listings*—Raymond S. Mistretta; *Publicity & SPE Reporter*—David L. Sahud; *Technical Societies Council Representative*—Lee Van Denburgh; *Professional Activities*—Vincent Sussman; *June Outing*—Harrison N. Van Duyne and William E. Decker.

After the meeting, two talks were given. Fred Ducca of Union Carbide Plastics Co. discussed "Faster Cycles With Hotter Electronic Preheat." Following, Neil Henry of Reed Prentice Div., Package Machinery Co., spoke on the Reed Jetflo—the first American made extruder-injection molding machine.

Ontario

Injection Molding of Polyethlene

Harry E. Watson

Some aspects of the injection molding of polyethylene in Europe were presented at the November meeting of the Ontario Section. Speaker was G. J. Gilvert, I.C.I., Welwyn Garden City, England, who is presently working for a year at the C-I-L laboratory in New Toronto on an exchange basis. Mr. Gilvert said injection molding consumed 30% of the polyethylene production in 1957 compared to 11% in the United States and Canada.

North Texas

Materials Selection

David A. Daniels

The proper selection of plastics materials for various applications was the basis for a talk by John Kent, technical service representative with Monsanto Chemical Co., Plastics Div., at the November meeting. Mr. Kent pointed out that a price-performance ratio should be established in the selection of a plastic material. He cautioned engineers about jumping into selection of a material without first determining what they want the material to do in performance, bearing in mind the cost of production.

Toledo

Reinforced Plastics

R.E. Dunham

At the November meeting, R. K. Gossett, 1958 SPE National President, outlined new programs being developed to increase the scope of the Society. Technical speaker was Norman Bonson of the Rand Development Corp., who described and demonstrated the Rand fiber-resin depositor. This machine is used in the manufacture of molded glass fiber articles by a spray technique rather than the hand lay-up method. The depositor sprays simultaneously accelerated resin, catalyzed resin and chopped glass fibers on the mold surface. This resin-fiber mixture is then worked into the contours of the mold by hand. Each coat is allowed to cure before succeeding layers are applied. The spray method is being used successfully in the manufacture of boats, wheelbarrows, contour chairs and caskets. It does not lend itself to the manufacture of small articles, nor is it expected to displace completely the hand lay-up technique of molding glass fiber articles.

The December meeting was devoted to reinforced plastics for sailboats and power boats. The theme of the meeting was to develop comparisons with regard to the material requirements for the two types of craft. Edward H. Cusworth, general sales manager of Crosby Aeromarine Co., presented the picture for power boats. In addition to emphasizing the many advantages of glass fiber reinforced boats, Mr. Cusworth showed a color movie depicting the manufacture and performance characteristics of power boats made from this material. Ray Greene, president of Ray Greene Associates, pointed out the success he has had with reinforced plastics for sailboats along with an interesting presentation on reinforced plastics air boats. He showed colored movies of the performance of plastics sailboats and air boats, and mentioned that the air boats have been very successful in rescue operations all over the world.

In the recent election of officers for 1959, the Toledo Section elected Jim Hyland, President; Bob DeBrock, Vice President; Ed Romay, Secretary; and Pete Swartzbaugh, Treasurer. New Directors elected were Frank Rosenberger, Bob DeBrock and Ed Romay.

Cleveland

Sequential Impact Molding

R. L. Huber

The 59th program of the Cleveland Section was held on January 19, 1959. G. D. Gilmore, vice president in charge of engineering and J. Decker, vice president and general manager of Bopp-Decker Plastics, Inc., Clawson, Mich., presented a new molding method.

Pinpoint gating is the forerunner of sequential impact molding and is a preliminary method of withholding material until given pressure is reached then allowing flow into cavity. Rated capacity of the machine is claimed rather than 50% of capacity as achieved by conventional multi-cavity systems. Smaller gates, runners and sprues are therefore permitted but more accurate tooling is necessary in this system. Internally heated nozzles and sprue bushings in effect eliminate sprues themselves. Timer control rather than volume control is a simplified explanation of this system's function. This new system is one worthy of careful investigation.

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ABOUT MEMBERS

James E. Simpson, head of Ferro Corp., Plastic Color Section, was one of four Ferro employees honored for outstanding contributions to the company's progress during 1958. Mr. Simpson, shown here receiving a certificate from Ferro's board chairman, Robert A. Weaver, was cited for his achievements in the development of new products for the plastics industry.

James E. Simpson (left) receives award from Robert A. Weaver, board chairman of Ferro Corp.

William P. Gideon, III, has been appointed head of the newly-formed plastics sales development group for Eastman Chemical Products, Inc., Kingsport, Tenn. He will correlate the work of the Tenite development laboratory with needs of the industry. Mr. Gideon, formerly in charge of the Tenite plastics sales office in Kansas City, is a graduate of the University of Tennessee with a B.S. in Chemical Engineering. He is affiliated with the Kansas City Section of SPE.

Walter R. Kosy recently joined Marbon Chemical as a technical service representative for Detroit and Eastern Michigan. Prior to joining Marbon, Mr. Kosy was a sales engineer for General Industries Co., where he had been employed since 1955. He also spent five years with Chrysler Corp. as a project engineer on rubber and plastics, and eight years with Lyon, Inc., working on plastics and other materials. An affiliate of the Detroit Section, he is a graduate of Wayne University.

Howard M. Gadberry, Kansas City Section, has been named assistant manager of the Chemistry and Chemical Engineering Div., Midwest Research Institute. Mr. Gadberry, a graduate of the University of Kansas, was with Phillips Petroleum Co. for three years before joining the Institute in 1946. He has been section head since 1954, directing and administering programs in product develoment and special research problems.

Mortimer H. Nickerson has joined Arthur D. Little, Inc., as a staff associate in the Research and Development Div. For the past 15 years he was chief chemist for DeBell and Richardson, Inc. An affiliate of the Western New England Section of SPE, Dr. Nickerson received his Ph.D. in organic chemistry from the Massachusetts Institute of Technology in 1940.

John T. Milon has been transferred to the Los Angeles branch office of Allied Chemical Corp. Since 1955 he has served with the National Aniline Sales Office in Chicago. He is a member of the American Chemical Society and SPE's Chicago Section.

Nathan S. Beekley, Jr., former senior chemical engineer in the development department of Goodyear's Chemical Div., has been appointed special representative in the division's New York district. He graduated from Tri-State College, Angola, Ind., with a degree in chemical engineering, and joined Goodyear in 1955 with extensive experience as a chemist and chemical engineer in various phases of the rubber and plastics industries. He is a member of the American Chemical Society, Akron Rubber Group and the Cleveland-Akron Section of SPE.

N.S. Beekley, Jr.

G.E. Pickering

George E. Pickering is co-founder and general manager of the newly-established firm Air-Formed Products Corp., Nashua, N.H., which will specialize in the design, manufacture and sale of equipment services to the blow molding industry. A member of the Pioneer Valley Section, Mr. Pickering was formerly associated with Plax Corp., Foster Grant Co., Northern Industrial Chemical Co., and the Naval Ordnance Plastics Laboratory.

Oscar Niemi has joined Marbon Chemical as a technical service engineer. He was previously employed for 17 years by Santay Corp., where for the past 10 years he was general superintendent in charge of the injection molding department. In his new position, Mr. Niemi will assist customers in working out their injection molding problems. He is a member of the Chicago Section.

O. Niemi

D.C. Hawk

David C. Hawk has been appointed manager of technical service for Cary Chemicals, Inc. He was formerly chief chemist with The Ansionia Wire and Cable Co. A graduate of Earlham College, Mr. Hawk has been associated with Belden Mfg. Co., B.F. Goodrich Chemical Co. and Cornish-Blackinton Co. He is a member of the Southeast New England Section of SPE.

J. G. Fuller

G.J. Godfrey

George J. Godfrey has been appointed technical director of the Reed Plastics Corp., Worcester, Mass. Mr. Godfrey is a graduate in chemistry of the University of Michigan, 1941. Most recently, he was associated with Koppers Co. as manager of the Chemical Division Color Section. Other previous positions were with Celanese Corp. of America and the U.S. Army Chemical Warfare Service. Mr. Godfrey is affiliated with the Pittsburgh Section of SPE.

Jack G. Fuller, President of the Southern California Section of SPE, has been appointed sales manager for Chemtrol in Lynwood, Calif. For the last ten years Mr. Fuller was associated with Hercules Powder Co. where he was senior technical sales representative with the Los Angeles office.

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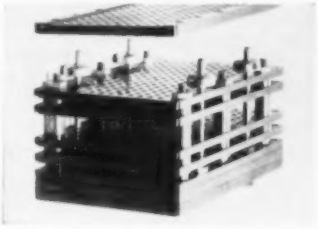

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Ralph M. Knight has been named manager of Polyolefin Planning & Applications for U.S. Industrial Chemicals Co., Div. of National Distillers & Chemical Corp., it was announced by Dr. Robert E. Hulse, Executive vice president of National Distillers & general manager of the U.S.I. Division. In this new position, Mr. Knight will be responsible for long-range planning and coordination of U.S.I.'s polymer development program and will also direct the company's Polymer Service Laboratories in Tuscola, Ill. Mr. Knight is a member of the American Institute of Chemical Engineers, SPE from the N. Y. Section, the SPI and Tau Beta Pi.

Herbert D. Oliver, Jr., was named sales representative in charge of the Kansas City, Mo., sales office of the plastics division, Eastman Chemical Products, Inc., it was announced by D. C. Williams, vice president of the Eastman Kodak Co. subsidiary. Mr. Oliver was previously attached to the company's Cleveland, Ohio office. He holds a B. S. in chemistry from Virginia Military Institute, 1941 and is a member of SPE, Cleveland-Akron Section.

G. M. Taylor of Hercules Powder Co., Wilmington, Del., was appointed to head up the sales of the new chlorinated polyether plastics, Penton. Mr. Taylor joined Hercules in 1951 as a chemist at their Research Center in Wilmington and is now being transferred from the Detroit district to his new position in Delaware.

Other assignments which were also announced by Frank K. Shankweiler, director of sales for Hercules, include **Daniel G. Welsh,** plastic representative in the Wilmington area: **Paul Metzger,** plastic representative in the Los Angeles area. All appointees are members of SPE.

OBITUARY

Grayson W. Wilcox of New Canaan, Conn., died suddenly on November 27. Mr. Wilcox was a sales representative for the Durez Plastics Div., Hooker Chemical Corp. A mechanical engineer and graduate of Worcester Polytechnic Institute, he had been on the Durez sales staff since 1937. He was the inventor of the Wilcox vent plug, a valve used for automatic venting of gases from certain plastic molds. He was a member of SPI and the Connecticut Section of SPE.

Dr. John J. Chapman, died in Baltimore, Md. on April 29, 1958. He was director of the Dielectrics Laboratory at Johns Hopkins University in Baltimore, Md. Prior to this he was employed by General Electric Co. and was a member of AIRE. Dr. Chapman was also a member of SPE's National Education Committee and authored a list of texts on plastics engineering which appeared in the SPE Journal.

Jerome L. Miller, 38 of Great Neck, N. Y., died Dec. 21, 1958 of a heart atack. Born in Brooklyn, N.Y., he was secretary and asistant treasurer of Ideal Toy Corp. of Hollis, N.Y. Mr. Miller was an SPE member from the N. Y. Section.

Dr. Lee B. Storms, research and technical director of Red Spot Paint and Varnish Co., Inc., died suddenly on December 15, 1958. He had been associated with Red Spot since 1936. He attended Evansville College and the University of Vermont before going to Indiana University where he received his bachelor's degree in 1936. He also earned his master's and doctor's degrees from Indiana. From 1943 to 1946 he served in the Navy. He was a member of the Tri-State Section of SPE, American Chemical Society, treasurer of the Society of Vacuum Coaters and a director of the Evansville Association for the Blind.

Herbert A. Preiss, died Dec. 23, 1958 at the age of 46 as the result of an automobile accident. Until his death, Mr. Preiss was president of Plastics Materials Corp. of Hicksville, L. I., which he founded in 1952.

Starting in plastics in 1932 with the John W. Masury & Sons, he later joined Bakelite Corp. in Bound Brook. After associating with A. Bamberger Corp., he engaged with Anton Bamberger to organize American Molding Powder & Chemical Corp.

An SPE member of the N.Y. Section, he resided in Stony Brook, L. I., where has was active in community affairs. Surviving are his wife, three children and his parents.

Two Technical Reports on Polymeric Materials

Two reports of Air Force-sponsored research on polymeric materials, one dealing with the effects of space charges on mechanical and adhesive properties and the other with polymerization characteristics of experimental monomeric compounds, have just been released for industry use.

Effects of Space Charge in Polymeric Materials on Mechanical and Adhesive Properties. S. M. Skinner, E. L. Kern, and M. K. Park, Case Institute of Technology for Wright Air Development Center, U. S. Air Force. Jan. 1958. 132 pages. (Order PB 131770 from OTS, U. S. Department of Commerce, Washintgon 25, D. C., $2.75.)

The purpose of this research was to examine the effects which may be anticipated, or measured, which result from the presence of space charge in polymeric materials. Stress was given to those areas in which experimentation might prove productive. One major conclusion was that space charge exists in polymeric materials in the vicinity of interfaces with chemically different materials. Among other results of the reasearch, it was found that the polymers may determine the presence of traps or fixed charge distribution; that space charge causes definite changes of electrical and mechanical properties of the polymers; and that enormous modifications in adhesive strength can be obtained by different surface treatments.

Polymerization Studies on Monomers and Evaluation of Derivative Polymers: Part 2. F. B. Jones, R. A. Markle, P. B. Stickney, and R. G. Heiligmann, Battelle Memorial Institute for Wright Air Development Center, U. S. Air Force. Mar. 1958. 101 pages. (Order PB 131778 from OTS, U. S. Department of Commerce, Washington 25, D.C. $2.75.)

This report describes research to determine the polymerization characteristics of a group of experimental monomeric compounds and a preliminary evaluation of the potential of the resulting polymeric products as thermally stable and solvent-resistant rubbers and plastics. Work with addition polymers included polymerization of some fluorine-containing olefine oxides, and copolymerization of perfluoropropylpropenyl ketone with a series of butadienes, of perfluoromethylpropenyl ketone with butadiene, and of perfluoroheptylpropenyl ketone.

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*Measured at 10 rpm on a Brookfield viscometer at 25°C.

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Vol. I—Quality Control for Plastics Engineers, $3.98, members; $4.95, non-members.

ANTEC PREPRINT BOOKS

Vol. V, 1959, New York City, 96 papers. $7.50, members; $12.50, non-members. Single preprints of individual papers, Vol. V, while they last, $0.25 each, members; $0.40 each, non-members.

Vol. IV, 1958, Detroit, 94 papers. $5.00, members; $7.50, non-members.

Vol. III, 1957, St. Louis, 60 papers. $5.00, members; $7.50, non-members.

RETEC PREPRINT BOOKS

★ AUTOMOTIVE
Plastics for the Automotive Industry—Detroit Section, 6 papers. $2.00, members; $3.50, non-members.

★ BUILDING
Plastic Trends in Building Construction—Southern California Section, 12 papers. $3.00, members; $4.50, non-members.

★ ELECTRONICS
Plastics in Electronics—Golden Gate Section, 8 papers. $2.50, members; $3.75, non-members.

Plastics for Airborne Electronics—Southern California Section, 10 papers. $3.00, members; $4.50, non-members.

★ EPOXIES
Epoxy Resin Symposium—Upper Midwest Section, 10 papers. $3.00, members; $4.50, non-members.

★ INJECTION MOLDING
Advances in Injection Molding—two books: Chicago Section, April 1958, 4 papers, and Philadelphia Section, November 1958, 6 papers. Either book: $2.00, members; $3.00, non-members.

★ PACKAGING
Plastics in Packaging—Western New England Section, 9 papers. $3.00, members; $4.50, non-members.

★ POLYETHYLENE
Polyethylene Properties and Uses—Cleveland-Akron Section, 8 papers. $3.00, members; $4.50, non-members.

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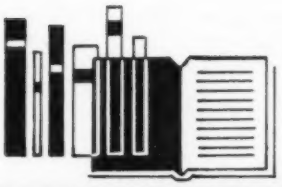

BOOK REVIEWS

Compilation of ASTM Standard on Plastics

American Society for Testing Materials, Philadelphia, 1958. 1108 pp., $8.00.

For 21 years Committee D-20 on Plastics has been developing specifications and standard testing methods for the plastics industry. To this edition 43 standards, not appearing in the previous 1957 edition, have been added. Significant new standards include specifications for: Nonrigid Vinyl Chloride Plastic Sheeting (D 1593); Glass Fabric Reinforced Epoxy Resin Laminates (D 1592); and Polymethylstyrene Molding and Extrusion Material (D 1595).

New Material includes a group of standards on plastic pipe with specifications covering dimensions of SWP and IPS sizes for cellulose acetate butyrate, and acrylonitrile-butadiene-styrene pipe. Also included are methods for short- and long-term hydrostatic pressure tests of plastic pipe. These pipe standards have been developed jointly by the ASTM and by the Society of the Plastics Industry.

Also included in this new edition are tentative abbreviations of terms relating to plastics (D 1600). These new abbreviations have been developed in an effort to standardize a short-hand notation for some of the more generally used complicated chemical names. For example: acrylonitrile-butadiene-styrene plastics in the new notation are simply ABS plastics.

All of the 191 ASTM standards applicable to the plastics industry appear in the new "Compilation of ASTM Standards Relation to Plastics."

The Properties and Testing of Plastics Materials

A.E. Lever and J. Rhys. First American Edition. Chemical Publishing Co., New York, 1958. 197 pages, $4.75.

This book outlines methods of test for plastics materials, and gives some condensed information as to properties of some plastics. The purpose of the book as stated by the authors is to "provide a 'source-book' or reference for those engaged in the testing of plastics."

The book is divided into chapters on general principles, physical, thermal, optical and electrical properties, other chemical and physical properties, and identification and analysis. An appendix summarizes properties and special tests for a variety of industrial materials, including a broad range of thermoplastic resins, laminates, textiles, fibers and foams. Each of the chapters is subdivided into more specific properties—electrical properties, for example, having subsections on dielectric strength, resistance, tracking, power factor and dielectric constant. Each section, in turn, contains brief discussions of the property, methods of test which may be used, and references to sources describing the subject in greater detail.

The authors have done an excellent job of reviewing the recent literature, and of classifying these references and compiling them in a single volume in convenient accessible form. This book appears especially outstanding for the extent and completeness of its references. A book of this scope could not in its limited size cover the subject completely. The book is not sufficiently critical to indicate preferred answers as to tests needed to characterize a material, best methods of test, or the relative value of new or revised methods. However, the detailed references are adequate to lead to this information.

This book should be a very useful starting point for anyone interested in testing plastics, and is recommended as a worthwhile reference work.

B.M. Walker
Resistoflex Corp.

Physical Chemistry of High Polymers

M.L. Huggins. John Wiley and Sons, Inc., New York, 1958. 175 pages, $6.50.

This is not a textbook in the usual sense, as the contributions of the author (which are noteworthy and many) are emphasized. This results, in some instances, to only a passing reference to whole areas of endeavor in the field of polymer physical chemistry. However, in the area of the author's work, solution properties and structure analysis of cellulose and its derivatives and proteins, the treatment is precise and concise.

This will be a valuable book to those having interests similar to the author's. As the information is more broadly presented elsewhere, however, most plastics engineers will find little immediate need for this book.

E.H. Merz
Monsanto Chemical Co.

Federal Food, Drug and Cosmetic Act, 1953-57

Vincent A. Kleinfeld and Charles Wesley Dunn. Commerce Clearing House, Inc., Chicago, 1958. 1127 pages, $25.00.

This is the fourth volume of a series which started in 1938 and, since that time, gave a very well documented report of the court decisions regarding food, drug and cosmetic cases. As such, this book is most valuable to anyone dealing with products under supervision of the FDA, principally now that the President has signed the approved Williams Law which definitely concerns plastic packaging materials. The fact that a few reputable manufacturers were tried because they did not fully comply with the law is the best proof that everyone should be fully informed on this subject.

This book gives the reader all the information he wants and enables him to draw his own conclusions in order to protect himself. Besides analyses of cases, this valuable book contains the FDA Act, new regulations, standards, annual reports, cumulative tables and index.

Dr. Louis C. Barail
Barail Associates

Separation and Purification of Materials

Rolt Hammond. Philosophical Library, Inc., New York, 1958. 327 pages, $10.00.

As the title indicates, this book is concerned with the improvements and newer methods evolved for the separation and purification of various materials. Consequently, the book will be of great interest to chemical engineers, plant engineers and process engineers. It will have very limited interest to those men concerned with the plastics industry other than the large companies who manufacture plastic raw materials.

The book is divided into seven chapters delving into the various methods of separation, starting with the separation of solids from solids and progressing through the separation of solids from liquids, solids from gases, and so forth. Further, the book covers a wide range of process methods. It covers such items as purification of metals and organic compounds by zone melting to the distillation of sea water to the purification of fissionable materials. In fact, the book can almost be considered a summary or handbook of the newer methods used for the separation of chemical and raw materials. At the end of each chapter is a limited bibliography and a source for the equipment and machinery described in the book. All of these sources are companies located in England, naturally, since the book was written in England.

The book is written in a very easily read style and covers the various subjects briefly and adequately. Adequate bibliography is included so that additional information on any specific type of separation can be obtained.

Since the subject selected is extremely broad, the information on any particular type of separation is of necessity limited and brief. However, that which is presented has been handled well. For those involved with this particular type of problem, the book would be a good starting point for information.

Robert Steinman, Ph.D.
Garan Chemical Corp.

Fluid Dynamics and Heat Transfer

James G. Knudson and Donald L. Katz. McGraw-Hill Book Co., New York, 1958. 576 pp., $12.50.

This book, a new and worthy member of the McGraw-Hill series in Chemical Engineering, is a volume of more restricted scope than its title indicates. The fluid dynamics treatment is largely concerned with closed conduit flow. The omission of extended treatment of compressible flow leads to an emphasis on liquids, with gas flow treated less fully. Liquid flow in open channels is not treated. Heat transfer discussion is limited to convection. Conduction and radiation mechanisms are not included. The general, and common, problems of heterogeneous media, processes involving change of state, or chemical reaction are largely outside the scope of the book. The book treats capably the fundamentals of the problems common to the familiar classes of closed conduit heat exchangers.

The reader is assumed to possess reasonable facility with differential equations. With the emphasis on theoretical derivations, only enough experimental data are given to support the reasonableness of the theory. The bibliographies, at the chapter ends, are extensive and emphasize recent publications. Some subjects of special interest (e.g., heat transfer with liquid metals, laminar flow, and flow in the entrance section of closed conduits), are given separate chapters. For the most part, the mathematical treatment in the text is consistent with the classical representation of the problems and their solutions. While the study of the contents of this book may well be recommended to those concerned with designing convection-heat exchangers, the reader should not expect the ready-reference handbook-type of utility, which other publications in this field offer. There is much value here, but the reader will probably have to devote some effort to mastering it.

Charles H. Fuchsman

Fundamental Concepts of Inorganic Chemistry

E.S. Gilraeth. McGraw-Hill Book Co., New York, 1958. 421 pages, $7.50.

The author calls this an elementary approach to certain theoretical concepts useful in the fields of chemistry and physics. However, it is rather an excellent textbook summary of both past and current explanations for atomic and subatomic structure and activity. Most recent theory is that atoms can be broken down into at least 20 different particles, and so the centuries-old search for the fundamental particle goes on.

The theories of Dalton, Thomson, Rutherford, Planck, Pauling, Bohr and others are described. The old periodic table, in spite of its deficiencies, is still very useful. Radioactivity and nuclear transformation are discussed, with some fascinating notes on how these are being put to everyday use in medicine, agriculture and industry. The author discloses some of the problems associated with our double standard of atomic weights (chemical and physical).

The serious student will learn that it is easier to explain atomic phenomena in equations than by words or models. There is no simple, collective way of describing the manner in which atoms influence each other.

Phillip i. Johnson
Diamond Alkali Co.

Concise Encyclopedia of Atomic Energy

Edited by Frank Gaynor. Philosophical Library, New York. 204 pp., $6.00.

This is, we believe, the most concise and easy to read text book on Atomic Energy. As the name implies, it is written in the alphabetical way of a dictionary and encyclopedia, which simplifies the selection of subjects.

Each element is described by chemical symbol, group of the periodic table, name of discoverer, date of discovery, atomic number and weight, melting and boiling points, specific gravity, stable isotopes, radioisotopes. All members of the radioactive families are also thoroughly described. There are over 2000 entries, numerous charts, condensing basic data, and illustrations.

This manual at college level will interest many a plastics engineer, as the plastics industry is benefiting so much from radioisotope research.

Dr. Louis C. Barail
Barail Associates

Grundzuge der Vacuum-Verformung (Elements of the Vacuum Forming Process)

Alfons Thiel. Rudolf Zechner Verlag, Speyer/Rhein, 1957. 122 pages, price DM 8.80.

This little book on a relatively new but rapidly growing technique of thermoplastic product fabrication represents the first volume of the Kunststoffbucherei, a project started by the publishers of *Der Plastverarbeiter*, a widely circulated German plastic trade journal.

Present practices of the vacuum forming process are described in detail and are excellently illustrated with photographs and drawings. The author draws heavily on his personal experiences in the field. Various chapters deal respectively with the bases of the vacuum forming process, principles of pressure and temperature, details of forming equipment, and negative vs. positive forming.

Besides the basic discussion of the process, secondary operations such as trimming, printing, surface finishing and heat sealing are also briefly treated. A valuable addition for the beginner in this field are: a table of German equipment manufacturers with detailed information on size and type of machines manufactured; a table of German thermoplastic sheeting manufacturers with types and sizes of materials as well as typical applications; and a brief chapter outlining methods for costing vacuum formed products.

The author wrote this book, according to the introduction, with the following motto: "From practical experience—for practical experience." One can readily agree that he has succeeded in presenting a highly practical guide to the vacuum former.

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